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NOTES ON THE GEOLOGY OF THE CABO BLANCO AREA, VENEZUELA

By

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Research Associate in Geology
The Florida State University

March 15, 1957

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NOTES ON THE GEOLOGY OF THE CABO BLANCO AREA, VENEZUELA

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ABSTRACT

This paper describes the Tertiary and Quaternary sediments of the Cabo Blanco area and discusses briefly their structural involvement and geologic history. Two new names, Catia and Maiquetía, are proposed as members or facies differentiates of the Playa Grande formation, and a new formation name, the Abisinia, is proposed for Quaternary deposits immediately pre-dating the Recent ones.

INTRODUCTION

Cabo Blanco is a small, low-lying cape fronting the Caribbean Sea 15 kilometers (9 miles) northwest of Caracas, Venezuela. Just south of the cape, and extending parallel with the shore in an east-west direction, are a series of hills composed of Tertiary and Quaternary sediments to which the name Cabo Blanco was first applied by Humboldt in 1801 and which are still so designated (under the classification of group) by present-day geologists. The oldest formation of the group is not fossiliferous but several of the younger formations are, and some of the fossils contained in one or another of the younger formations have been mentioned or described by a number of writers ever since the publication of Humboldt's "Relation historique du voyages aux régions equinoxiales du Nouveau Continent" in 1814-1825. It seems, however, that the fossils from a particular locality or formation have been determined as one age by some authors and a different one by others, whereas conversely, an identical age has been assigned in some instances to formations occupying widely different positions in the stratigraphic column. Geologists in Venezuela have long been aware of these conflicting interpretations. As a preliminary step in resolving the problems, the Cabo Blanco area was mapped in 1947-1948 by Gabriel Dengo (1953) and then in more detail in 1954 by professors and students of the Department of Geology and Mines, Central University of Venezuela. The results of the latter work are contained in a student thesis, parts of which have been summarized in the "Léxico Estratigráfico de Venezuela" (1956) by Prof. Royo y Gómez (Cuaternario en Venezuela, p. 199-209) and Prof. Frances de Rivero (Cabo Blanco, Grupo, p. 116-121). A geologic and topographic contour map[1], scale 1:5,000, accompanies the thesis, and it is that informative map, revised to accord with this writer's observations, which appears in the present paper. Since the whole of the area shown was surveyed by the writer with pace and compass only, the planimetry of the map presented is of limited accuracy even though all traverses were adjusted to certain points previously established on the thesis map.

In 1955 and 1956, the writer spent a number of weekends mapping the geology of the Cabo Blanco area, and in this paper the results of the investigation are discussed. My remarks are based on independent field work, but I have been guided by the contributions of my predecessors, especially those affiliated with the Central University of Venezuela, who are to be commended for doing a job that had to be done and in doing it well. I also wish to thank the Socony Mobil Oil Company de Venezuela for permission to publish this article.

GENERAL REMARKS

The area discussed in this paper lies north and west of the Maiquetía airfield which is 19 kilometers (11.5 miles) by road from the outskirts of Caracas. South of the airfield is the Cordillera de La Costa, or Venezuelan Coast Range, which is composed for the most part of metamorphic rocks and attains a maximum elevation at Pico Naiguatá of 2,765 meters (9,072 feet). As shown on the geologic map by Dengo (1953), the seaward flank of the metamorphics is fringed by Tertiary and Quaternary deposits, and these comprise the terrain around Cabo Blanco from which locality they extend westward toward Catia La Mar, and eastward toward Maiquetía. The maximum width of this belt is only 2.4 kilometers, but this small area cradles such a wealth of geologic phenomena that it may harbor the key for unraveling the late Cenozoic history of northern Venezuela. For example, the attitudes of the strata and

[1] Mapa Geológico-Topográfico del Area de Cabo Blanco, 1954. The authors' names appearing on the map are: A. Alarcon, C. Alcantara, P. Gamboa Bauza, A. Menendez, J. V. Solis, and M. Tello Campodonico.

the unconformities between formations suggest several periods of movement and erosion since mid-Tertiary time, while the character of the sediments indicates deposition in nonmarine, paralic, and marine environments during the intervals of their accumulation. The ages of the formations should eventually be determinable from a study of the fossils (now being undertaken by the writer), and the chronology of tectonic events should be deducible from a detailed investigation of the folds and faults. The faults noted seem to be of a normal, reverse, and strike-slip variety, and the latest of them may well have developed in Quaternary time. Finally, the slightly inclined terraces at successively lower levels document the process of marine abrasion and of differential uplift or eustatic change during Pleistocene and Recent times.

TOPOGRAPHY AND DRAINAGE

Topographically, the most dominant features of the Cabo Blanco area are the hills paralleling the coast and the terraces at Playa Grande and the Maiquetía airfield. The Maiquetía airfield, at an elevation of some 35 meters (115 feet)[2], is built on a plain composed of outwash from the mountains. As pointed out by Royo y Gómez (1956, p. 200), the plain seems to have originated through aggradation of the piedmont and by scour and fill of the sea before the terraced surface attained its present elevation. A higher and somewhat older terrace is present at the village of Playa Grande. At the east end of the village, the terrace surface has an elevation of about 62 meters (203 feet), and the red, sandy and gravelly clay composing the terrace contains occasional large corals and some small gastropods which resemble those inhabiting the strand today. Thus, the Playa Grande terrace is of marine origin and was probably developed in the Pleistocene. Still older but smaller terraces are present at levels between 80 and 110 meters (262 and 361 feet) south and east of Playa Grande, while the oldest and highest terrace may be represented by the small gravelled surface 135 meters (443 feet) above sea level on which the Cabo Blanco lighthouse is situated. The youngest marine terraces are displayed along the present seashore. The coast road here and there follows an elevated beach some 3 to 5 meters above sea level, while the lowest and most recent bench is just awash of high tide. This bench consists of conglomerates (containing occasional Recent shells) and is being formed through the cementation of present-day beach debris.

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[2] All elevations mentioned are from the Mapa Geológico-Topográfico del Area de Cabo Blanco, 1954.

The largest stream in the Cabo Blanco area is Quebrada Las Pailas, the headwaters of which are in the Coast Range 4.5 kilometers due south of Cabo Blanco. The quebrada is generally dry except during heavy rains. A narrow watershed separates Quebrada Las Pailas from the coast, and the highest point of this drainage divide is occupied by the Cabo Blanco lighthouse at an elevation of approximately 135 meters. The short streams flowing north to the sea, and south to Quebrada Las Pailas, have steep gradients. The channels are usually dry, but when it rains torrentially, as it does occasionally in the wet season, run-off is rapid, and a considerable amount of sand and gravel is washed down them.

STRATIGRAPHY

CABO BLANCO GROUP

Except for Recent deposits, the entire group of sediments lying north of the Coast Range metamorphics in this area has long been referred to as Cabo Blanco, and this name is retained even though a mid-Tertiary to Quaternary time span is involved.

The Cabo Blanco group is made up of a heterogeneous array of strata which from bottom to top are divided into the following units:

Las Pailas formation
Playa Grande formation
Mare formation
Abisinia formation

LAS PAILAS FORMATION

TYPE LOCALITY

The Las Pailas formation outcrops on both sides of the watershed between Quebrada Las Pailas and the coast. The type section is exposed along the coastal side of the watershed and extends from the mouth of Quebrada Las Pailas westward for a distance of 2.6 kilometers. The formation was first described by Frances de Rivero (1956).

DESCRIPTION

The outstanding characteristic of the Las Pailas formation is the light gray color of the coarser clastics which are present throughout the section but more abundantly so in the upper part of it.

The succession of strata within the Las Pailas formation is conformable from bottom to top. The lower half of the formation consists of mudstones, siltstones, and fine sandstones, interbedded with occasional coarse sandstones and conglomerates. The upper half of the formation consists largely of conglomerates and coarse sandstones with occasional intervals of the same type of fine-grained sediments that make up the lower half of the formation.

At whatever position they occur, the siltstones and fine sandstones of the Las Pailas formation are soft, gray to tan in color, and generally highly micaceous. These fine sediments may occur in well-defined beds, they may be intermingled with coarser material, or they may be homogeneous and massive. Parting planes of the siltstones are often coated with a soft, soapy textured mudstone which is also found interbedded or interlaminated with the fine sandstones. At W-9, the siltstone contains peatlike plant fibers, and at several localities, it contains irregular nodules, some three centimeters or so in diameter, of fine-grained, indurated sandstone. In some places, there are soft, gray sandstones disseminated with rusty brown particles.

The mudstones of the Las Pailas formation are also distributed throughout the entire Las Pailas section but are thinner and not so abundant as the siltstones. The mudstones are soft to moderately compact, are either dull gray or chocolate brown in color, and are often soapy textured or glazed in appearance. They usually occur interbedded or intermingled with the siltstones or fine sandstones but are sometimes intercalated with coarser sediments. Near the headwaters of the two streams 900 meters and 1,300 meters southwest of the lighthouse, there are several feet of pure mudstone at the top of the Las Pailas section where they immediately and unconformably underlie the basal conglomerates of the Playa Grande formation. Elsewhere, the mudstones often contain nests of light gray silt and sand, just as the siltstones and sandstones contain pockets of the greasy mudstone.

The coarser clastics of the Las Pailas formation consist of granular sandstones and conglomerates. These are rather poorly cemented and are generally light gray in tone although there is a zone some 700 meters long and 20 meters wide just north of and paralleling the fault between section lines C-C' and D-D' where the conglomerates are brown in color. The Las Pailas conglomerates are composed of subangular to subrounded granules, pebbles, and cobbles embedded in a coarse, somewhat friable sandstone which may contain a little disseminated gypsum. The larger constituents of the conglomerates are mainly quartz, gneiss, and schist, and these were in all probability originally derived from the Coast Range whose present foothills lie a short distance south of the Maiquetía airfield. The quartz is usually milky white but some of it is smoky blue. The gneiss is light-colored and streaked with black femic minerals, and the schists are green and black and often highly micaceous.

Although the coarse clastics of the Las Pailas formation exhibit a little lenticularity and cross-bedding, individual beds are generally evenly disposed and separated by clean-cut parting planes.

THICKNESS

Along section line C-C', where the Las Pailas formation is exposed at the shore and extends southward to the Bruscas fault, the thickness of the Las Pailas section is 375 meters (1,230 feet). The maximum thickness of the formation is undoubtedly greater than this and depends in part on how far out to sea the south-dipping beds extend.

STRATIGRAPHIC BOUNDARIES

The base of the Las Pailas formation has not been observed, and its relationship to the rocks immediately underlying it is not known. On the other hand, uplift and erosion of the Las Pailas prior to the deposition of the overlying Playa Grande formation has resulted in a marked angular unconformity between the two formations, with a difference in dip between them of as much as 40 degrees. In mapping, this unconformity is considered the upper boundary of the Las Pailas formation.

AGE AND CORRELATION

The Las Pailas formation is devoid of shelly organisms although it does contain a little vegetable material. The formation is probably of continental origin and may have been laid down in a fresh-water or brackish water lagoon. The conglomerates contain reworked rocks which are the same as those composing the nearby Venezuelan Coast

Range, and it is inferred that the Las Pailas material was derived from this range, if not in the immediately preceding cycle, then from a formation which itself was made up of debris from the then existing mountains.

The absence of determinable fossils precludes a definite age assignment for the Las Pailas formation. However, its position below upper Tertiary beds, and its resemblance to certain formations whose age has been bracketed elsewhere in Venezuela, suggest that this formation was laid down in mid-Tertiary time.

PLAYA GRANDE FORMATION

OCCURRENCE

The Playa Grande formation was first described by Frances de Rivero (1956). It takes its name from the village of Playa Grande where part of the formation forms the slopes below the terrace on which the village is situated. From Playa Grande, the formation extends westward to the beach resort of Catia La Mar. East of Playa Grande, it is exposed along the upper part of the lighthouse scarp and in the low hills just north of the Maiquetía airfield.

DESCRIPTION

The Playa Grande formation consists of a variegated assemblage of rocks and starts at the base with a brown conglomerate. The type locality of this basal conglomerate is the scarp below the lighthouse where it attains its maximum thickness of about 65 feet. In the western part of the area, it occurs as a ribbon along the northern and upper flank of the coastal scarp and, near the Costa fault, it is only a foot or two in thickness. The deposit is a lenticular body lying with pronounced angular unconformity on the Las Pailas formation but in general conformability with overlying members of the Playa Grande formation. The conglomerate is composed mainly of quartz, gneiss, and mica schist in granule to boulder dimensions. The quartz is white to yellowish brown, and some of the schist pebbles are flattened as they may be elsewhere throughout the Playa Grande formation. Near the headwaters of the gully 70 meters west of the lighthouse, a large block of gray, banded sandstone lies erratically within the conglomerate, and inasmuch as this sandstone, as well as some of the other fragmental material, is identical with that in the Las Pailas formation, there is little doubt that some of the constituents of the basal conglomerate have been reworked from the Las Pailas formation. The conglomerate is haphazardly sorted, poorly cemented, and nonfossiliferous. It marks the base of the Playa Grande formation, but in view of the lenticular nature of the Playa Grande deposits, it is probable that the conglomerate as such is not always present at this position.

Since there is no connecting stratigraphic sequence between the Playa Grande formation in the northern part of the Cabo Blanco area and that of the south, it may be appropriate to divide the Playa Grande formation into two members for which the names Catia and Maiquetía are proposed. The Catia member, which is much the thicker of the two, is exposed north of the Bruscas fault, whereas the Maiquetía member is exposed south of the fault and extends from the vicinity of Abisinia westward along the north edge of the Maiquetía airfield. The Maiquetía facies with its characteristic dull gray rocks has not been observed north of the Bruscas fault although south of the fault the Maiquetía member is interfingered with certain sediments that are lithologically identical with those of the Catia member. However, since the Catia beds immediately overlie the basal conglomerate of the Playa Grande formation, they are believed to occupy the lower part of the formation, whereas the Maiquetía beds which unconformably underlie the Mare formation are presumed to occupy the upper part of the Playa Grande formation. Nevertheless, nowhere is there a continuous section across the grain of the Playa Grande formation, and the relationship of the two members as given above is suggestive rather than definitive.

The thickest development of the Catia member is on the Litoral anticline near the village of Playa Grande and along the scarp south of the coast road leading to Catia La Mar. Here and elsewhere, the Catia member consists mainly of siltstones, sandstones, and conglomerates which are interbedded with a number of coquinas, an occasional mudstone, and sporadic limestones. Macroscopic and microscopic fossils are generally present in greater or less abundance throughout the Catia member, and many of the rocks are calcareous.

The siltstones of the Catia member are usually massive but in places they are poorly bedded. The massive variety has a yellowish tan appearance, and this color is distinctive of the member particularly at Playa Grande where the formation is exposed in new road cuts. The bedded variety, on the other hand, is generally gray to tan in aspect. The siltstones are soft or hard, the former often grading irregularly into hard, fine-grained sandstones which are both calcareous and gypsiferous, and produce the knobby surface so characteristic of certain beds throughout the Playa Grande formation. Another feature of the siltstone-sandstone deposits is the occurrence, normal to the bedding, of long, roughly cylindrical sandstone bodies as much as four centimeters in diameter. The branching nature of some of these casts and the tapering conical form of others lead the writer to surmise that they are the fillings of plant stems, perhaps of mangrove.

Although many of the sandstones of the Catia member are massive, fine-to-medium-grained, and calcareous or gypsiferous or both, a few of them are hard, flaggy, and sparkling, while others are coarse-grained to conglomeratic. Fossils are rare or absent in the more siliceous sandstones but are present in the calcareous ones.

The conglomerates of the Catia member are of two types. One is poorly consolidated but well sorted, and contains rounded cobbles and boulders of metamorphic rocks in a coarse earthy matrix. The other variety is a heterogeneous one containing large and small fragments of gneiss, schist, and quartz, and rough, irregular chunks of coarse sandstone. These latter conglomerates are thicker and more extensive than the well-sorted variety but both of them may be overlain or underlain by siltstones, sandstones, or shell beds. The shell beds occur at various levels within the Catia member, and in places the fossils are so abundant that they form impure coquinas. Examples of these are at W-21 and W-22, and the *Ostrea* bed east of W-22. The *Ostrea* bed is about 6 feet thick and directly overlies a well-sorted boulder conglomerate. Other coquinas composed largely of the barnacle *Balanus* are present in the scarp east of the Costa fault where they lie a short distance above the basal conglomerate of the Playa Grande formation. However, a similar barnacle coquina is present in the Maiquetía member in the scarp southwest of W-11, and this bed could be much higher in the Playa Grande section than the foregoing.

The total thickness of the Catia member of the Playa Grande formation is not known. On the Litoral anticline, the thickness from the Costa fault to the contact with the Abisinia formation is 525 feet, and from the Costa fault to the west end of section line F-F', it is 770 feet. These are believed to be minimum thicknesses.

The Maiquetía member as defined in this paper refers to the assemblage of shales, siltstones, sandstones, and conglomerates outcropping north and west of the Maiquetía airfield and lying unconformably below the Mare formation. The rocks are generally drab gray and dull tan in color, and produce a rather cheerless looking terrain. Associated with these rocks, however, are lighter colored sediments similar to those of the Catia facies.

The easternmost outcrop of the Maiquetía member is near Abisinia at W-25 where it projects through talus on the south flank of the Punta Gorda anticline and unconformably underlies boulder gravels of the Abisinia formation. From this unconformity downward, the Maiquetía member is composed of the following strata:

Feet	*Description*
5	Cobble conglomerate; matrix of coarse earthy sand.
2	Dull tan, fine-grained sandstone.
5	Lenticular pebble conglomerate with dull tan to drab gray, fine-grained sandstone.
3	Drab gray and tan, fine-grained sandstone.
1	Blue-black, gritty siltstone grading down to pebble conglomerate.
10	Yellow-tan, fine-grained sandstone interbedded with pebble conglomerate; gray, soapy textured mudstone; tan, finely micaceous siltstone; and drab gray siltstone.
5	Talus.

At W-23 on the north flank of the Punta Gorda anticline, the Maiquetía member is unconformably overlain by three feet or so of fossiliferous Mare sandstone which in turn is capped disconformably by 15 feet of Abisinia gravels. From the unconformity at the base of the Mare wedge, the Maiquetía member consists at the top of about 20 feet of boulder to pebble conglomerates whose contained fragments are larger above than they are below. The rocks which make up this conglomerate are mostly greenstones, gneiss, mica schist, graphite schist, and garnetiferous schist, together with a little quartz. Below this poorly sorted conglomerate is a one-foot bed of evenly sorted, flattened, and elongated cobbles resting directly on a 7-foot reef composed of *Lithothamnium* which is garnished with a fair assortment of mollusks. Under the reef is another heterogeneous conglomerate some two feet thick down to the bottom of the outcrop at road level. The *Lithothamnium* reef is exposed along the south side of the coast road for a distance of 150 meters and is the largest of such reefs observed in the Cabo Blanco area. Somewhat farther west, and along the same general strike, there are other outcrops of *Lithothamnium*-bearing strata, and these seem to be stratigraphically close to the reef described above.

In Quebrada Mare Abajo and on the lower slopes of the hills adjoining it, the Maiquetía member is made up of soft, dull gray and dull brown clay shales interbedded with, or grading into, dull gray gypsiferous siltstones and sandstones, and interlensed with dull-toned argillaceous grits and rather loosely cemented pebble conglomerates. Near W-12, the clay shales are encrusted with a rusty yellow substance which is believed to be the mineral jarosite and, in the small tributary east of W-12, the grits contain platy selenite layers a few millimeters in thickness. The pebbles of the conglomerates consist mainly, as they do in both older and younger conglomerates of the Cabo Blanco area, of gray-black mica schist, olive-green schist, white quartz, gneiss, and other metamorphic rocks. The schist pebbles are the most abundant, and many of them are flattish, smooth, and rounded at the edges. It is estimated that the thickness of the Maiquetía member at Quebrada Mare Abajo is 100 feet. At the south, the Maiquetía member is directly overlain, with angular unconformity, by the basal fossiliferous grits of the Mare formation. Downdip and to the north, the Maiquetía member is blanketed with Quaternary sediments beneath which there may be another 100 feet or more of Maiquetía sediments lying above the exposed 100 feet. The thickness of the Maiquetía section below the lowest exposed bed is not known.

Approximately 280 meters west of Quebrada Mare Abajo, Maiquetía strata reappear in the bed of a small stream where they are again unconformably overlain by basal fossiliferous grits of the Mare formation. Here, the average dip of the Maiquetía beds is 30 degrees north (as contrasted with four degrees north of the Mare grits), and it is estimated that the exposed Maiquetía section is about 85 feet thick. In this stream, the Maiquetía member is made up of alternating pebble conglomerates and gray to chocolate brown siltstones overlain by soft marly sands. The matrix of the conglomerates is a coarse, friable sandstone in which are embedded flattened pebbles of schist, subangular to subrounded pebbles of white quartz, and minor amounts of gneiss. The siltstones are soft and drab gray to chocolate brown in color, and contain, in one place or another, thin shale partings with nests of ashy gray silty sand, and lamellae of decayed vegetable material. The siltstones here are reminiscent of those in the upper part of the Las Pailas formation at W-9.

A partial but continuous section of the Maiquetía member is exposed in the stream-cut scarp 50 meters southwest of W-11. At this locality, the lower 50 feet consist of drab gray and dull brown granule, pebble, and cobble conglomerates with some dark gray clay shales and silty shales at the base. The top of this sequence is conformably overlain by a coquina-like bed containing many barnacles, and this in turn is overlain by marly sandstones and knobby calcareous sandstones which are identical with such sandstones in the Catia member north of the Bruscas fault. Similar calcareous sandstones underlie the conglomerates and are exposed on both flanks of the Maiquetía anticline.

Maiquetía beds, some of them steep, are also exposed in Quebrada Las Pailas just west of the Maiquetía airfield. Here, there are at least two separate *Lithothamnium* banks interbedded with selenite-bearing gray sandstones, bleached gypsiferous clays, micaceous sandstones, pebble conglomerates, and massive gray mudstone containing nodules of hard white chalk.

FOSSILS

Macroscopic and microscopic fossils are present throughout the Playa Grande formation, and these indicate that the beds were laid down in shallow marine waters. One of the most interesting of the fossil occurrences is the calcareous alga *Lithothamnium*. This occurs in both the Catia and Maiquetía facies but has been observed more frequently in the latter. The largest *Lithothamnium* reef observed is at Punta Gorda (W-23) and consists of pinkish, subovate colonies of algae averaging about four centimeters or so in diameter. On top of the reef, and associated with it, are a number of mollusks of which *Oliva, Venericardia, Glycymeris,* and a beautifully ornate *Codakia* have been identified.

Along the scarp west and east of W-15 at Playa Grande, and particularly in the gully west of W-15 is *Pecten arnoldi* Aguerrevere which is the largest and most robust of the bivalves collected in the

Playa Grande formation. At W-15, the following Foraminifera have been recognized: *Textularia, Liebusella, Quinqueloculina, Pyrgo, Robulus, Marginulina, Saracenaria, Lagena, Nonion-Nonionella, Elphidium, Buliminella, Bulimina, Virgulina, Bolivina, Uvigerina, Reusella/Trifarina, Discorbis, Eponides, Rotalia, Siphonina, Amphistegina, Cassidulina, Globigerina, Orbulina, Globorotalia, Cibicides,* and *Planulina.* With these Foraminifera occur some ostracods.

At W-21 are the mangrove (?) casts mentioned earlier, and these are immediately underlain by strata containing many specimens of *Ostrea* cf. *haitensis* Sowerby. Farther east, at W-22, and stratigraphically lower than the foregoing, is another fossil bed which is filled with *Ostrea* cf. *haitensis, Spondylus, Pecten,* and *Balanus,* as well as an occasional thick-shelled *Chama.* The *Ostrea* bed east of W-22, whose trace is shown on the geologic map, is a near-coquina and lies about 60 feet stratigraphically lower than the W-22 bed.

Coquinas consisting principally of the barnacle *Balanus* are present in discontinuous reefs in the scarp east of the Costa fault. These may be as much as four feet thick and have been observed in an interval 20 to 60 feet above the basal conglomerate of the Playa Grande formation. Another *Balanus* bed, a foot or so thick, outcrops in the cliff 50 meters southwest of W-11 (Cross Section B-B'-B''), but its position with reference to the basal conglomerate is not known. It may be considerably higher stratigraphically than the ones referred to above.

At W-4 in the south bank of Quebrada Las Pailas, and at stream level, is a dark blue, slightly gritty mudstone overlain by soft, tan siltstones which contain, among other fossils, *Dosinia, Venericardia, Conus, Architectonica,* and *Turritella.* The same species of *Turritella* (often to the exclusion of all other shells) occurs in many localities around W-4, and although some of these Turritellas are from the same horizon, others of the same species are from different horizons within the Playa Grande formation of this area.

AGE

Many of the fossils in the Playa Grande formation closely resemble those of the overlying Mare formation although there are some which seem to be restricted to one or the other of these formations. A careful study will be required to establish the age of the Playa Grande formation, but the writer tentatively considers it to be Miocene-Pliocene.

MARE FORMATION

TYPE LOCALITY

The type locality of the Mare formation is the area adjacent to Quebrada Mare Abajo where it constitutes part of the hills overlooking this small stream. From the Mare Abajo drainage system, the formation extends along the edge of the Maiquetía airfield and continues northwestward for a distance of 500 meters. Here it disappears, as it does east of Quebrada Mare Abajo, under a mantle of younger debris, although farther east small wedges of the formation are exposed south of the village of Mare Abajo and on the south flank of the Punta Gorda anticline.

The Mare formation was first described by Frances de Rivero in the "Léxico Estratigráfico de Venezuela" (1956).

DESCRIPTION

The Mare formation is a shallow-water marine deposit. It is about 40 feet thick at the type locality but attains a maximum thickness of perhaps 60 feet elsewhere. The lower 10 to 15 feet are made up of incoherent grits and sands containing many well-preserved fossils. This lower member starts as a pebble to granule gravel or "grit" (with occasional stringers of cobbles) and grades upward to a sand of decreasing coarseness. The upper 30 feet or so of the Mare formation consist of tan, homogenous, and slightly compacted silts of a fine and even texture. These silts conformably overlie the coarser sediments at the base of the Mare formation, but the contact between them is usually rather sharp. Like the grits, the silts of the Mare formation are also highly fossiliferous, albeit more so below than above, and, at the top of the formation, the silts may be barren of visible fossils.

STRATIGRAPHIC RELATIONS

By definition, the fossiliferous grit represents the base of the Mare formation, and this lies unconformably on one member or another of the Playa Grande formation. At the type locality, where the Mare formation is in contact with the Maiquetía beds, the unconformity is markedly angular. With respect to its upper boundary, the Mare formation is overlain disconformably by nearly horizontal deposits of the Abisinia formation. Near the edge of the Maiquetía airfield where the

Mare and overlying Abisinia formations are in contact, the Mare beds are also nearly flat although northward therefrom they dip locally to the north.

FOSSILS

A distinguishing feature of the Mare formation is its many well-preserved shells. One of the most striking of these is the bivalve *Macrocallista maculata* (Linné) which occurs abundantly in the silts just above the contact with the lower grits, but is rare, if not absent, in the grits themselves. Other mollusks, however, are present in both the silts and the grits, and some of these are *Architectonica, Conus, Oliva, Terebra, Marginella, Distorsio* cf. *clathratus* (Lamarck), *Glycymeris,* and *Trigoniocardia.* Additional to the mollusks, the Mare formation contains corals, isolated spheres of *Lithothamnium,* echinoids, Bryozoa, and barnacles as well as many Foraminifera and some ostracods. The Foraminifera identified from samples W-13 and W-14 are given in the following list. W-13 refers to genera found in the grit, and W-14 to those in the silt. All others, and these are in the majority, occur in both members: *Cornuspira* (W-14), *Textularia, Quinqueloculina, Spiroloculina,* (?)*Triloculina* (W-13), *Pyrgo* (W-14), *Lagena, Nonion-Nonionella, Elphidium, Buliminella, Bulimina, Bolivina, Uvigerina, Virgulina* (W-14), *Angulogerina* (W-13), *Reusella* (W-14), *Discorbis, Pulvinulinella, Siphonina* (W-13), *Amphistegina, Cassidulina, Globorotalia, Cibicides* (W-13), *Cibicidella* (W-13), *Cibicidina* (W-14), and *Anomalina* (W-14).

In comparing the faunas of the Mare formation with those of the Playa Grande, the similarity of many of the fossils as contrasted with the relatively few restricted ones, is notable. This might indicate that the two formations are not so widely separated in geologic time as the angular unconformity suggests.

AGE AND CORRELATION

Although the presence of fossils in the Mare formation has been noted in several papers as far back as 1887 (Lorié), and as recently as 1956 (Frances de Rivero), the results of a comprehensive study of the larger forms have not yet beeen published. So far as this writer can determine, the Mare formation as defined and limited in the present paper has been called middle Miocene, Miocene-Pliocene, Pleistocene, or

Quaternary. At one time, Wendell P. Woodring (in Kehrer, 1939) was of the opinion that a collection of fossils from Cabo Blanco, which he examined for the Caribbean Petroleum Company, was middle Miocene in age. In his discussion, he stated that *Macrocallista maculata* is the most abundant species in the collection, and I feel reasonably certain that the formation he referred to is the Mare. In a later paper (1954), Woodring wrote that the lower Pliocene of Venezuela is represented by the Cabo Blanco formation, but I do not know if Woodring's Cabo Blanco formation included several units of Cabo Blanco group as described herein or referred specifically to the Mare formation. Frances de Rivero (1956) suggested "that the Mare is probably Pleistocene, although the presence of the gastropod *Strombina* may indicate an older age".

The age of the Mare formation cannot yet be precisely established, although an integrated study of the many different fossils should be productive of significant results. In the meanwhile, the writer is inclined to consider the Mare formation as Pliocene in age, and that it was deposited at about the same time as the Punta Gavilan formation at Punta Gavilan in the State of Falcon, Venezuela (Suter, 1937).

ABISINIA FORMATION

OCCURRENCE

This formation is named after the small settlement of Abisinia[3] which lies along the east foot of the Maiquetía airfield. The formation underlies the airfield and forms many of the terraces in the Cabo Blanco area.

DESCRIPTION

The Abisinia formation, as introduced and here defined, consists of clays, silts, sands, and gravels which post-date the Mare formation and pre-date Recent sedimentation.

The clays and silts are reddish in the western part of the Cabo Blanco area, and are gray to mottled gray and tan as well as highly micaceous in the east. The sands are fine to coarse and are reddish brown or brown in color. The gravels are made up of quartz, sandstone, schist, greenstone, gneiss, and miscellaneous metamorphics in a matrix of sand,

---

[3] Razed in 1956 for new constructions.

and the constituents are of pebble to boulder size. The coarser gravels are generally more heterogeneous than the finer ones which in places are nearly exclusively quartz-bearing. Schist cobbles are often flattened like those in the older Playa Grande conglomerates.

The thickness of the Abisinia formation probably does not exceed 40 feet.

STRATIGRAPHIC RELATIONS

The Abisinia formation is conformable to disconformable with the underlying Mare formation. At W-25, near the northeast corner of the Maiquetía airfield, boulder gravels of the Abisinia formation disconformably overlie a thin wedge of the Mare formation, and where the latter is absent, they overlie folded Playa Grande beds with angular unconformity. South of Quebrada Mare Abajo, highly micaceous clays of the Abisinia formation seem to be nearly conformable with the light tan silts of the Mare formation, and in this area, the contact between the two formations is difficult to establish. At the east end of the village of Playa Grande near W-30, the base of the Abisinia formation is a horizontally disposed red, pebbly sand, and this overlies a low-dipping marl of the Playa Grande formation. There is an irregular contact between the two formations, and this indicates a period of erosion prior to the accumulation of the Abisinia deposit. At W-30, the two formations contain fossils, the Playa Grande with some cemented with the marl, the Abisinia with an occasional large, red-stained coral head as well as a number of small gastropods and a few larger bivalves. The Abisinia deposit which is about 12 feet thick at this locality, grades up to a red, sandy clay on which there is a terraced surface at an elevation of approximately 62 meters (207 feet). The occurrence of the geologically "young" fossils suggests that the terracing was caused by marine abrasion and deposition in fairly late time (Pleistocene ?), while the presence elsewhere of lower terraces developed on the Abisinia formation suggests that there have been several stages of uplift or eustatic change since the Pleistocene.

AGE

Primarily from its stratigraphic position above the Mare formation, but also from the character of the few fossils observed, the Abisinia formation is believed to be Pleistocene in age.

Small gastropods identical with those at W-30 have been collected at W-10 on the watershed 140 meters southwest of the lighthouse. The Abisinia formation at the latter locality is at an elevation of 100 meters (328 feet) or so, and contains, in addition to the small gastropods and some ostracods, the following genera of Foraminifera: *Bathysiphon, Textularia, Quinqueloculina, Nonion, Elphidium, Rotalia, Eponides, Discorbis, Amphistegina, Globigerina, Globorotalia, Cibicides, Planulina, Cibicidella,* and *Anomalina.* Although these Foraminifera suggest that the Abisinia formation was laid down in late geologic time, they are not in themselves diagnostic, and it is primarily from its stratigraphic position that the Abisinia formation is presumed to be Pleistocene in age.

RECENT

Included in the Recent category are weathered surficial deposits, present day stream debris, re-transported clays, sands, and gravels, and the flat conglomerate reefs occuring along the shore and in some of the stream beds near the shore. It is often impossible to differentiate Recent gravels from those of the Abisinia formation, and in such areas, the ensemble has been mapped as undifferentiated Quaternary.

STRUCTURE

The most striking structural feature of the Cabo Blanco area is the coastal monocline which extends from the Costa fault eastward toward Quebrada Las Pailas for a distance of 2.5 kilometers. The monocline is composed for the most part of Las Pailas beds which dip 25 to 56 degrees to the south. At the lighthouse scarp, the Las Pailas formation is unconformably overlain by the Playa Grande formation which also dips south but at lower angles. South of the lighthouse ridge, the Las Pailas formation reappears and terminates against the Bruscas fault. The monocline is believed to be the south flank of a high whose crest is beneath the sea at an unknown distance north of the present shoreline. The "crest" of the "high" may be the axis of an anticline, it may be a fault, or it may be a buried ridge of pre-Las Pailas rock, possibly of the same metamorphics that constitute the present Coast Range.

The largest fault of the Cabo Blanco area is the Bruscas. This fault crosses Quebrada Las Pailas at W-27, and continues therefrom in an east-northeast direction to the small stream 250 meters west of the mouth of Quebrada Las Pailas. At W-27 where the Las Pailas formation is in juxtaposition with knobby fossiliferous limestone of the Playa Grande formation, the Las Pailas is squeezed nearly vertically against a narrow syncline of the Playa Grande at the fault itself. The fault plane seems to dip northward at perhaps 70 to 80 degrees, and one gets the impression that the Bruscas fault is a high angle reverse, dipping north and under the upthrown side. In the stream near section line B'-B'', the Bruscas fault cuts only the Las Pailas formation, with the fault plane forming the axis of a sharp syncline. The Bruscas fault continues west of W-27 although its position is difficult to determine because of heavy vegetation and Quaternary cover. The prolongation as shown on the geologic map is inferred from occasional outcrops of Las Pailas rocks on the north side, and from the trenchlike valley of Quebrada Las Bruscas. This stream has been converted into a drainage ditch along the side of the road and has been dug deep enough through a low divide to connect with a small stream flowing in the opposite direction. At one place along the road, there is a boggy area which the writer thinks might be due to sag along the fault. The Bruscas fault undoubtedly continues still farther to the west although it cannot be traced because of surface cover.

Although its fault plane has not been observed, the location and approximate strike of the Costa fault are inferred from the disposition of the adjacent formations. South-dipping Las Pailas beds on the east have been brought into contact with Playa Grande beds on the west, the latter displayed on an anticlinal nose plunging rather steeply to the southwest near the fault itself. From the geologic pattern on either side of it, the Costa fault is presumed to be downthrown to the west, or to be a strike-slip fault with the northwest side having been displaced to the right or northeast. The Costa fault undoubtedly extends farther to the northeast where it is hidden by the sea, and to the southwest where it is covered by terrace deposits.

Minor faults have been observed at a number of localities. One of them lies 350 meters east of W-15, another about 100 meters south of the axis of the Litoral anticline, and a third some 300 meters east of section line D-D'. The second of these is a small normal fault striking N 10° W, down to the east, with 18 inches of throw. This fault was noted near the headwaters of a gully which has since been bulldozed away and can no longer be seen. The third fault is also a normal one and is downthrown to the south. The clearly exposed fault plane dips 48 degrees to the south. Still another fault is the one cutting across Quebrada Las Pailas west of the Maiquetía airfield. The trend is generally east-west, and its extent is probably greater than is evidenced at the surface.

Three anticlinal reversals, all of them developed in the Playa Grande formation, have been observed, and these are, from east to west, Punta Gorda, Maiquetía, and Litoral. The difference in the strata on the south and north flanks of the Punta Gorda feature indicates that it is faulted along the axis. Little is known about the Maiquetía anticline, and the northwest trend is inferred from the attitude of the beds on the flanks. The conjectured configuration of the fold is shown on section line B-B'-B''. To the north, the Maiquetía anticline is truncated by the Mare Abajo fault, and to the south, it is presumed to continue below the terrace deposits of the airfield. The Litoral anticline is a southwest-plunging nose diverging off from the Costa fault. The beds dip as high as 52 degrees a short distance away from the fault, but they flatten out rather rapidly down the plunge as portrayed graphically on cross section E-E'.

GEOLOGIC HISTORY

Prior to the deposition of the Las Pailas formation, the Cabo Blanco area is visualized as having been an east-west depression, framed on the landward side by the then existing Coast Range and separated from the sea by a barrier on the north. Into this depression was deposited the nonmarine Las Pailas formation which consists of clastics derived from the metamorphic complex of the Coast Range. Following the accumulation of the Las Pailas deposits, there were several cycles of uplift, erosion, and marine incursion, these events having taken place in post-Las Pailas time (Miocene ?) and during the intervals represented by the Playa Grande, Mare, and Abisinia formations (late Miocene to Quaternary). Since the Coast Range was involved in these events, it is clear that this segment of northern Venezuela is tectonically unstable, and that the Cabo Blanco area itself has been involved in movement and rejuvenation from at least as far back as mid-Tertiary up to the present.

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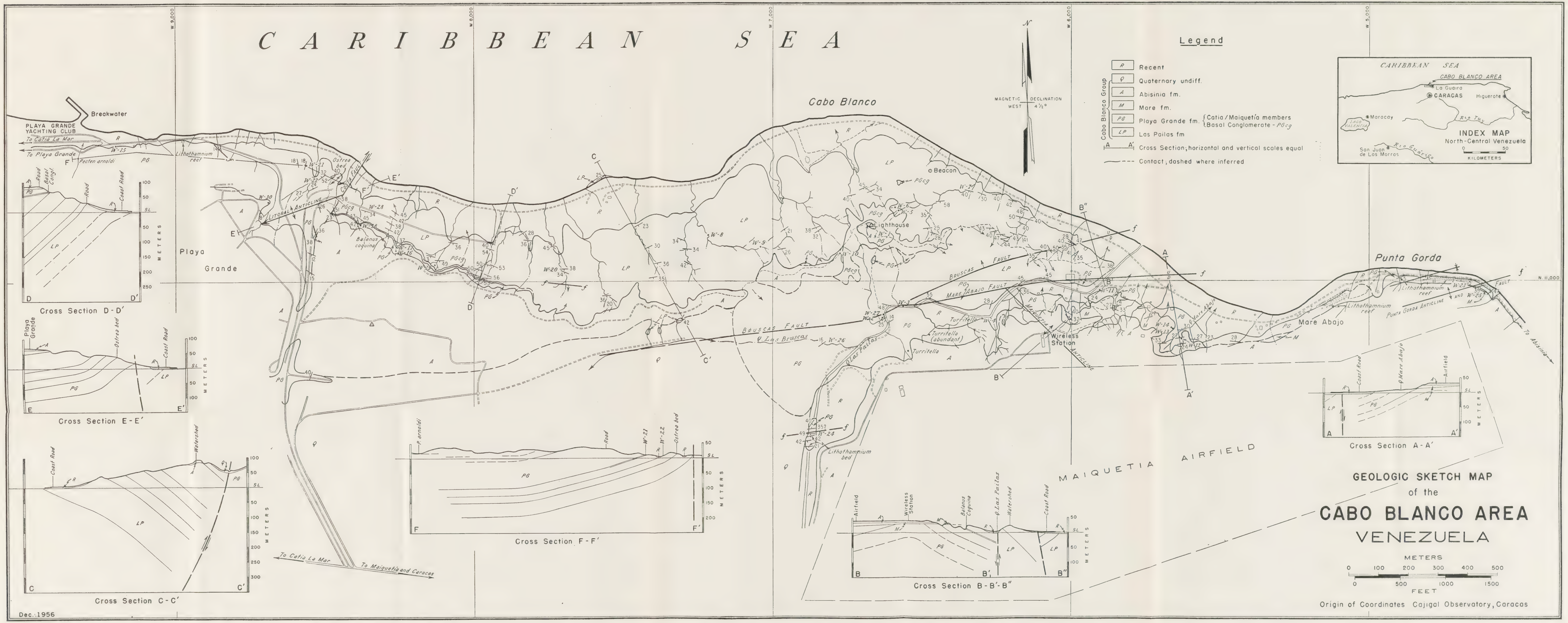
CARIBBEAN SEA
Cabo Blanco
Punta Gorda
Playa Grande
Mare Abajo
Breakwater
PLAYA GRANDE YACHTING CLUB
To Catia La Mar
To Playa Grande
Pecten arnoldi
Lithothamnium reef
Ostrea bed
LITORAL ANTICLINE
Balanus coquina
Beacon
Lighthouse
Wireless Station
BRUSCAS FAULT
MARE ABAJO FAULT
Las Bruscas
Las Pailas
Turritella
Turritella (abundant)
Lithothamnium bed
PUNTA GORDA ANTICLINE
ANTICLINE
To Abisinia
To Catia La Mar
To Maiquetia and Caracas
MAIQUETIA AIRFIELD
MAGNETIC DECLINATION WEST 4½°
N
W. 9,000
W. 8,000
W. 7,000
W. 6,000
W. 5,000
N. 11,000
Legend
R Recent
Q Quaternary undiff.
A Abisinia fm.
M Mare fm.
PG Playa Grande fm. {Catia/Maiquetía members; Basal Conglomerate - PGcg
LP Las Pailas fm
Cabo Blanco Group
A A′ Cross Section; horizontal and vertical scales equal
Contact; dashed where inferred
CARIBBEAN SEA
CABO BLANCO AREA
La Guaira
CARACAS
Higuerote
Maracay
LAGO VALENCIA
Rio Tuy
San Juan de Los Morros
Rio Guárico
INDEX MAP
North-Central Venezuela
0 50
KILOMETERS
Cross Section D-D′
Cross Section E-E′
Cross Section C-C′
Cross Section F-F′
Cross Section B-B′-B″
Cross Section A-A′
Airfield
Wireless Station
Balanus coquina
Las Pailas
Watershed
Coast Road
Road
Basal Congl.
Ostrea bed
P. arnoldi
W-21
W-22
METERS
SL
GEOLOGIC SKETCH MAP
of the
CABO BLANCO AREA
VENEZUELA
METERS
0 100 200 300 400 500
0 500 1000 1500
FEET
Origin of Coordinates Cajigal Observatory, Caracas
Dec. 1956

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VARIATION IN AMERICAN OLIGOCENE SPECIES OF LEPIDOCYCLINA

By

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May 10, 1957

Paleontological Research Institution
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VARIATION IN AMERICAN OLIGOCENE SPECIES OF LEPIDOCYCLINA*

W. STORRS COLE
Cornell University, Ithaca, N. Y.

ABSTRACT

Three species of American Oligocene lepidocyclines belonging to the subgenus *Lepidocyclina* are discussed, illustrated, and a summary of their stratigraphic and geographic distribution is presented. A key for the recognition of all the known American Oligocene and Miocene species of this subgenus is given. *Operculinoides bullbrooki* Vaughan and Cole which occurs in association with some of these species is transferred to the genus *Amphistegina.*

INTRODUCTION

Variation between individuals of the same species in various genera of larger Foraminifera has been known for some time. Vaughan (1928; 1933) was one of the first American workers to emphasize that many of the specific names in the genus *Lepidocyclina* had been given to specimens which were individual variants of a limited number of species. He stated (Vaughan, 1933, p. 6) "The amount of variation in many species of orbitoids is bewildering."

As more information has accumulated, it has been possible to substantially reduce the number of specific names which had been used to designate specimens which could be proven to belong to only one species. This reduction in names has been advantageous in the interpretation of the stratigraphic and geographic distribution of the basic species. Cole (1944, p. 60) demonstrated that *Lepidocyclina* (*Polylepidina*) *antillea* Cushman, specimens of which had been recorded under several different specific names in Mexico and the Gulf Coast of the United States, was a geographically widespread, middle Eocene species. Likewise, *L. (Nephrolepidina) chaperi* H. Douvillé which had been known by numerous specific names represented one widely dispersed upper Eocene species (Cole, 1953a, p. 23).

Vaughan (1928, p. 155) argued for the retention of subspecific names for variants of certain species of *Lepidocyclina.* He cited the *L. ocalana* series as an example. However, it now appears that such a

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nomenclatural device does not serve any useful purpose either in explaining the stratigraphic or geographic distribution of this species and its variants. Therefore, all the variants of *L. ocalana* should be combined under this specific name. To this list should be added *L. georgiana* Cushman which is a synonym of *L. ocalana.*

Recently, Dr. Hans G. Kugler, consulting geologist to Trinidad Oil Company, Ltd., kindly sent me two samples from Morne Diablo quarry, one of the classic localities in Trinidad, B.W.I. As certain specimens from these samples were studied they appeared to resemble other well-known American species. But, as specimens from localities elsewhere were compared with the specimens from Trinidad, certain specific differences which had been used previously seemed to disappear. Therefore, a detailed study was undertaken to ascertain if certain established species could not be combined.

The samples from Morne Diablo quarry contain the following species:

Amphistegina bullbrooki (Vaughan and Cole)
Lepidocyclina (Lepidocyclina) giraudi R. Douvillé
mantelli (Morton)
waylandvaughani Cole
Miogypsina (Miolepidocyclina) staufferi Koch

Kugler (personal communication, February 1, 1957) wrote that Bolli believes that the sample from Morne Diablo quarry probably "represents the *Globigerinatella insueta* zone and slightly older."

FUNDAMENTAL CHARACTERS OF AMERICAN OLIGOCENE SPECIES OF *LEPIDOCYCLINA (LEPIDOCYCLINA)*

The subgenus *Lepidocyclina* is represented in the American Oligocene by species with two types of equatorial chambers. The species *L. (L.) yurnagunensis* Cushman has diamond-shape or rhombic equatorial chambers, whereas the other species assigned to this subgenus have hexagonal-shape equatorial chambers.

Species with hexagonal equatorial chambers can be differentiated in part into three groups of species on external appearance. One group represented by *L. (L.) asterodisca* Nuttall has a distinctly rayed test, another assemblage, characterized by *L. (L) giraudi* R. Douvillé, has large, distinct, raised pustules, and the final group, characterized by

L. (L.) canellei Lemoine and R. Douvillé, either is without pustules or they are small.

The specific determination within these groups depends on the features of the vertical section except in the case of those with rayed tests. Although *L. (Nephrolepidina) dartoni* Vaughan has a rayed test, *L. (L.) asterodisca* is the only rayed species of *L. (Lepidocyclina)* known to date from the American Oligocene.

The other species of *L. (Lepidocyclina)* with hexagonal equatorial chambers can be subdivided into three basic types on the character of the lateral chambers. *L. (L.) mantelli*, of which *L. (L.) forresti* and *L. supera* are synonyms, has lateral chambers with low openings between thick roofs and floors arranged in overlapping tiers. *L. (L.) canellei*, of which *L. (L.) matleyi* and *L. (L.) pancanalis* are synonyms, has lateral chambers with open rectangular cavities with thin roofs and floors arranged in regular tiers. *L. (L.) giraudi*, of which *L. (L.) parvula* is a synonym, has lateral chambers with more or less open cavities with moderately thick roofs and floors crowded irregularly between strong pillars.

L. (L.) waylandvaughani Cole is related to *L. (L.) mantelli* and *L. (L.) giraudi*, whereas *L. (L.) miraflorensis* Vaughan belongs to the *L. (L.) canellei* group. A key to the megalospheric specimens of species *L. (Lepidocyclina)* in the American Oligocene and Miocene follows:

KEY TO MEGALOSPHERIC SPECIMENS OF AMERICAN OLIGOCENE AND MIOCENE LEPIDOCYCLINA

A. Test stellate .... *L. asterodisca* Nuttall
B. Test not stellate:
    1. Equatorial chambers rhombic or diamond-shape .... *L. yurnagunensis* Cushman*
    2. Equatorial chambers except near the center hexagonal
        a. Vertical section with numerous, strong, irregularly distributed pillars .... *L. giraudi* R. Douvillé
        b. Vertical section without pillars or with small or moderate pillars
            1.′ Lateral chambers in definite regular tiers with open cavities:
                a.′ Lateral chambers short. *L. canellei* Lem. and R. Douvillé
                b.′ Lateral chambers long .... *L. miraflorensis* Vaughan
            2.′ Lateral chambers not in definite tiers:
                a.′ Cavities low, slitlike .... *L. mantelli* (Morton)
                b.′ Cavities open .... *L. waylandvaughani* Cole

**L. yurnagunensis morganopsis* Vaughan and *L. sanluisensis* Gravell are synonyms of *L. yurnagunensis.*

AGE OF THE SEDIMENTS

Vaughan and Cole (1941, p. 28) recorded the following species of orbitoids and miogypsinids from Morne Diablo:

Lepidocyclina (Lepidocyclina) forresti Vaughan [= *L. (L.) mantelli* (Morton)]
canellei Lem. and R. Douvillé
giraudi R. Douvillé
Miogypsina hawkinsi Hodson (= probably *M. (Miolepidocyclina) staufferi* Koch)

The samples sent by Kugler from Morne Diablo quarry contained these species, except *L. (L.) canellei*, and had in addition specimens of *L. (L.) waylandvaughani.*

The stratigraphic range of *L. (L.) mantelli* (including specimens previously identified as *L. (L.) supera* in the southern United States) is from the Marianna limestone into the Suwannee limestone, that is, from Rupelian to Chattian (Cooke *et al.*, 1943, table).

On the basis of larger Foraminifera Gravell and Hanna (1938, p. 987) proposed four zones for the Oligocene of the southern United States, namely, 1. the *L. (L.) mantelli* zone, 2. the *L. (L.) supera* zone, 3. the *L. (Eulepidina)* zone, and 4. the *Miogypsina-Heterostegina* zone. Inasmuch as *L. (L.) mantelli* and *L. (L.) supera* are considered to be the same species, the *L. (L.) supera* zone either must be eliminated or combined with the *L. (Eulepidina)* zone.

Moreover, Vaughan (1933, p. 41) found *L. (L.) supera* (= *L. (L.) mantelli*) in the Alazan shale of Mexico in association with *L. (Eulepidina) favosa,* and Cole (1944, p. 17) found *L. (L.) mantelli* in a well in Florida associated with *L. (L.) undosa.* At Duncan Church, Florida, (Cole, 1934, p. 22) *L. (L.) supera* occurred with *L. (Eulepidina) undosa.* Therefore, it would appear that the *L. (L.) mantelli* and the *L. (Eulepidina)* zones should be combined.

Cole (1938, p. 44) assigned beds in a well in Florida which contained *M. (M.) hawkinsi* and *M. (M.) venezuelana* (= *M. (M.) staufferi* Koch) (Cole, 1957, p. 323, 324) to the Suwannee limestone. These *Miogypsina*-bearing beds occurred in this well above beds containing *Lepidocyclina (Eulepidina)* and below others assigned to the Tampa limestone. The data to date suggest that neither orbitoids or miogypsinids occur in the Tampa limestone of Florida. This limestone is thought to be lower Miocene, Aquitanian, in age (Cooke *et al.*, 1943, table).

In Trinidad (Vaughan and Cole, 1941, p. 22) and Venezuela (Gravell, 1933, p. 35) *Miogypsina* occurs with *L. (Eulepidina)*. Therefore, in the Caribbean region only two zones which apparently overlap can be recognized, a lower one with *L. (Lepidocyclina)* and *L. (Eulepidina)* and an upper one with *L. (Lepidocyclina)* and *Miogypsina*. *Miogypsina*, however, may survive longer than does *Lepidocyclina* in which case a third zone of *Miogypsina* without *Lepidocyclina* may be present.

In Panama orbitoids and miogypsinids occur in the Culebra formation (Cole, 1953b) (*L. (L.) miraflorensis, L. (L.) waylandvaughani, L. (L.) yurnagunensis* and *M. (M.) antillea*) and in the La Boca member of the Panama formation (*L. (L.) giraudi, L. (L.) miraflorensis,* and *Miogypsina (Miolepidocyclina) staufferi*). These formations are assigned by Woodring (1955) to the lower Miocene.

Stainforth (1948, p. 1311) placed the Morne Diablo limestone in the Chattian. This assignment agrees with the stratigraphic occurrence of *L. (L.) mantelli* and *M. (M.) staufferi* in Florida and *L. (L.) waylandvaughani* in Mexico. However, *L. (L.) waylandvaughani* in Panama occurs in the upper Oligocene part of the Bohio formation (Cole, 1957, p. 314, 315, 327) and also in the upper Oligocene part of the Caimito formation and in the Culebra formation of Miocene age.

Eames (1953, p. 388) was of the opinion that all the beds in Venezuela and Peru containing *Miogypsina* should be placed in the Miocene. This concept was disputed by Stainforth (1954, p. 175).

In Panama *Miogypsina* occurs abundantly in the Bohio and Caimito formations (Cole, 1953a, p. 7; Cole, 1957, p. 314, 315). Woodring (1955) placed parts of these formations that contain *Miogypsina* in the upper Oligocene. However, if Eames' concept was followed a part of the *Lepidocyclina (Eulepidina)* beds of the Caribbean region would have to be placed in the Miocene.

Drooger (1952) reported *Miogypsina basraensis* (= *M. (M.) gunteri*) and *M. tani* (= *M. (M.) antillea*) from the Kapur limestone of Trinidad and *M. bronnimanni* (= *M. (M.) staufferi*) from the Morne Diablo limestone. These limestones are "slip-masses" in the Cipero formation (Cushman and Renz, 1947, p. 3; Kugler, 1950, p. 48).

Recently, Kugler (1954, p. 413) suggested that the base of the Miocene should be placed at the base of the *Globorotalia fohsi* zone.

The stratigraphic occurrences of the miogypsinids in the Kapur and Morne Diablo limestones are similar to those found in Florida and in Panama (Cole, 1957, p. 326). However, in Panama *Miogypsina* does occur in the Culebra formation and the La Boca member of the Panama formation, both of which are assigned to the Miocene (Woodring, 1955). Akers (1955, p. 651) assigned zones in Louisiana containing *Miogypsina* and *Heterostegina* to the Miocene, but these zones apparently are stratigraphically older than the *Globorotalia fohsi* zone. Therefore, if Kugler's assignment of the *G. fohsi* zone to the basal Miocene is correct, the *Miogypsina-Heterostegina* zone in Louisiana may be Oligocene.

Although Kugler (1954, p. 413) suggested that the base of the Caribbean Miocene should be placed temporarily at the base of the *Globorotalia fohsi* zone, Drooger (1956, p. 186) concluded that the zones characterized by *G. fohsi* "and *Globogerinatella insueta*, and at least the major part of the zone of *Globigerina dissimilis* must be placed in the Miocene."* If this suggestion were followed the Caribbean Oligocene would consist almost entirely of the zones characterized by *Globigerina* cf. *apertura* and *Globigerina ciperoensis.* In this same article (p. 188) Drooger plotted the stratigraphic ranges of the miogypsinids, showing their major development in the *G. dissimilis* zone.

However, there has been little information recorded to date in the literature regarding the relationship of the faunas of larger Foraminifera to the various zones established by means of planktonic Foraminifera. Moreover, Kugler (1954, p. 411) stated that most of the post-Eocene occurrences of larger Foraminifera in Trinidad are in "slipmasses" and, therefore, their exact stratigraphic position is difficult to determine.

Thus, the final correlation between the zones of planktonic Foraminifera and the ranges of the larger Foraminifera must be determined from other areas of the Caribbean region. Even when this is done, it is extremely doubtful if the ranges of the benthonic larger Foraminifera will correspond to any world-wide planktonic zonation as the time of

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*Kugler (personal communication, February 1, 1957) wrote that an article on the biostratigraphy of the Cipero formation is to be published soon by H. Bolli. In this article Bolli places the base of the Miocene at the base of the *Globigerina dissimilis* zone.

radiation of the benthonic types from centers of development should be longer.

If the Suwannee limestone, the Bohio formation, and a part of the Caimito formation are correctly assigned to the upper Oligocene, it would seem that in the Caribbean region the miogypsinids were well established before the Miocene regardless of their development in Europe and Africa.

From this summary it would appear that the Oligocene-Miocene boundary in the Caribbean area cannot be defined upon larger Foraminifera alone as may be done in the case of the Eocene-Oligocene boundary where numerous genera, such as *Asterocyclina, Pellatispira,* and *Pseudophragmina*, appear to be restricted to the Eocene. *Lepidocyclina (Lepidocyclina), L. (Nephrolepidina), L. (Eulepidina),* and *Miogypsina* occur in the Oligocene, but *L. (Lepidocyclina)* and *Miogypsina* extend into the Miocene. However, *L. (Nephrolepidina)* and *L. (Eulepidina)* appear to be restricted to the Oligocene.

To date *L. (L.) miraflorensis* appears to be the only species restricted to the Miocene as this species is known with certainty only in the Culebra formation and in the La Boca member of the Panama formation. Such species as *L. (L.) giraudi, L. (L.) waylandvaughani,* and *M. (Miogypsina) antillea* seem to range from Oligocene into the Miocene.

DESCRIPTION OF SPECIES

Amphistegina bullbrooki (Vaughan and Cole) Pl. 5, figs. 6, 7

1941. *Operculinoides bullbrooki* Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 44, 45, pl. 11, figs. 6, 7; pl. 12, figs. 4, 5.

Remarks.—This species superficially resembles compressed specimens of the genus *Operculinoides.* However, transverse sections show asymmetry characteristic of *Amphistegina.* Moreover, the extreme recurvature of the chamber walls near their distal ends is a character of *Amphistegina.*

It is easy to confuse specimens of *Operculinoides* and *Amphistegina.* At the request of Dr. Lloyd Henbest I examined thin sections from Hawaii in which he (Henbest in Stearns, 1938, p. 620) recorded *Camerina* sp. These specimens are not *Camerina* but *Amphistegina.*

Earlier, Cushman (1919, p. 51) described *Nummulites parvula* from St. Bartholomew. This is also an *Amphistegina.*

Lepidocyclina (Lepidocyclina) mantelli (Morton) Pl. 1, figs. 1-5, 7-9; Pl. 2, figs. 1, 6; Pl. 3, figs. 1-4; Pl. 4, figs. 1, 4, 6, 7; Pl. 5, figs.3, 5; Pl. 6, figs. 3-7

1833. *Nummulites mantelli* Morton, Amer. Jour. Sci., v. 23, p. 291, pl. 5, fig. 9.

1865. *Orbitolites supera* Conrad, Acad. Nat. Sci. Philadelphia, Proc., No. 2, p. 74.

1924. *Lepidocyclina (Lepidocyclina) supera* (Conrad), Vaughan, Geol. Soc. Amer., Proc., v. 35, p. 797, pl. 33, fig. 4.

1927. *Lepidocyclina (Lepidocyclina) forresti* Vaughan, U. S. Nat. Mus., Proc., v. 71, art. 8, p. 1, 2, pl. 1, figs. 1-4; pl. 2, figs. 1-6.

1927. *Lepidocyclina (Lepidocyclina) mantelli* (Morton), Vaughan, *idem,* p. 3, pl. 3, fig. 1.

1927. *Lepidocyclina (Lepidocyclina) supera* (Conrad), Vaughan, *idem*, p. 4, pl. 3, fig. 3.

1927. *Lepidocyclina mantelli* (Morton), Vaughan, Acad. Nat. Sci. Philadelphia, Proc., v. 74, p. 299, 300, pl. 23, figs. 1*a*, *b*, 2.

1927. *Lepidocyclina (Lepidocyclina) mantelli* var. *papillata* Vaughan, *idem,* p. 300.

1933. *Lepidocyclina (Lepidocyclina) supera* (Conrad), Vaughan, Smithsonian Miscell. Coll., v. 89, No. 10, p. 12, 13, pl. 29, figs. 1-3.

1934. *Lepidocyclina (Lepidocyclina) supera* (Conrad), Cole, Journ. Paleont., v. 8, No. 1, p. 23, 24, pl. 3, figs. 7-15; pl. 4, figs. 6, 7.

1944. *Lepidocyclina (Lepidocyclina) mantelli* (Morton), Cole, Florida Geol. Survey, Bull. 26, p. 70, 71, pl. 19, fig. 5; pl. 22, figs. 13-15.

1953. *Lepidocyclina (Lepidocyclina) mantelli* (Morton), Cole, U. S. Geol. survey, Prof. Paper 244, p. 21, pl. 18, fig. 13.

1953. *Lepidocyclina (Lepidocyclina) supera* (Conrad), Cole, *idem*, p. 244, pl. 18, fig. 12.

1953. *Lepidocyclina (Lepidocyclina) forresti* Vaughan, Cole, *idem*, p. 244, pl. 18, fig. 11.

Occurrence.—Florida to Mississippi in the Marianna limestone as *L. (L.) mantelli* and *L. (L.) mantelli papillata*, in the Byram marl as *L. (L.) supera,* in the Suwannee limestone as *L. (L.) supera;* Tampico Embayment, Mexico, in the Alazan shale as *L. (L.) supera*; Antigua in the Antigua formation as *L. (L.) forresti*; Jamaica, B.W.I., in the Moneague formation as *L. (L.) forresti* and *L. (L.) supera;* Trinidad as *L. (L.) forresti* and *L. (L.) supera;* Venezuela in the San Luis series as *L. (L.) forresti.*

Remarks.—Vaughan (1927a, p. 3, 4; 1927b, p. 299, 300) in studies of *L. (L.) mantelli* and *L. (L.) supera* was the first to record that certain specimens in a given population of *L. (L.) mantelli* possessed "small but well developed pillars" (1927a, p. 3). He noted that "This variety lies between the usually accepted *L. mantelli* and *L. supera*" (Vaughan, 1927a, p. 3). Later (1927b, p. 300) he proposed the varietal name *papillata* for specimens which "are not typical *L. mantelli*, but possess pillars and have minute papillae on the outer surfaces." Vaughan (1927a, p. 2) separated typical *L. mantelli* from *L. supera* by this characterization: "*L. mantelli* is a larger species and has longer lateral chambers; *L. supera* has well-developed pillars and papillae. . ."

Cole (1953b, p. 334) separated these two species in a key by the nature of the lateral chamber cavities. He stated that *L. mantelli* had "cavities long, slit-like," whereas *L. supera* had "cavities low, slightly arched, but with a distinct opening." These statements seemed to be correct when applied to selected individuals of these species as may be seen if the illustrations given by Cole (1953a, pl. 18, figs. 12, 13) are examined.

As additional thin sections were prepared, it became more and more doubtful if these species could be separated. A specimen (fig. 4, Pl. 1) from near Duncan Church, Washington County, Florida, is nearly identical to the specimen of *L. mantelli* illustrated as figure 1, Plate 1. Yet, other specimens (Cole, 1934, pl. 3, figs. 8-13) from near Duncan Church were identified as *L. (L.) supera*. The specimen (fig. 3, Pl. 1) from Robinson's Quarry is intermediate between typical *L. (L.) mantelli* (fig. 1, Pl. 1) and the topotype of *L. (L.) supera*. Vaughan (1927b, p. 300) identified the specimens from Robinson's Quarry as *L. (L.) supera*.

There is apparently complete gradation between specimens which have been named *L. (L.) supera* and others which have been called *L. (L.) mantelli*. Stratigraphically, therefore, *L. (L.) mantelli* extends from the Marianna limestone into the Suwannee limestone.

Previously, Cole (1953a, p. 21) demonstrated that *L. (L.) forresti* Vaughan was a synonym of *L. (L.) supera*. Therefore, it is possible now to recognize only one species, *L. (L.) mantelli*, where previously three species were thought to be. The following table gives the geographic and stratigraphic distribution of *L. (L.) mantelli* and the species of *Lepidocyclina* which occur with it.

OCCURRENCE OF *L. (L.) MANTELLI* AT SELECTED LOCALITIES

Gulf Coast of U.S.A.	Mexico	Trinidad	Venezuela	Jamaica, B.W.I.
Suwannee ls. with		Morne Diablo ls. with	San Luis series	Moneague fm. with
L. (L.) yurnagunensis		*L. (L.) canellei*	with	*L. (L.) canellei*
(E.) undosa		*giraudi*	*L. (L.) canellei*	*giraudi*
		waylandvaughani		
Byram marl				
Marianna ls. with	Alazan sh. with			
L. (L.) giraudi	*L. (E.) favosa*			
(E.) undosa				

Lepidocyclina (Lepidocyclina) giraudi R. Douvillé Pl. 4, fig. 3; Pl. 5, figs. 1, 2; Pl. 6, figs. 1, 2

1907. *Lepidocyclina giraudi* R. Douvillé, Soc. Géol. France, Bull., ser. 4, v. 7, p. 305-311, pl. 10, figs. 9, 10, 15, 16.

1919. *Lepidocyclina parvula* Cushman, Carnegie Inst. Washington, Publ. 291, p. 58, pl. 3, figs. 4-7.

1933. *Lepidocyclina (Lepidocyclina) parvula* Cushman, Vaughan, Smithsonian Miscell. Coll., v. 89, No. 10, p. 16, 17, pl. 7, figs. 1-5; pl. 8, figs. 3-5; pl. 9, figs. 1-4; pl. 10, figs. 1-6.

1933. *Lepidocyclina parvula crassicosta* Vaughan and Cole in Vaughan, *idem*, p. 17-19, pl. 8, figs. 1, 2; pl. 10, fig. 7; pl. 24, fig. 1.

1933. *Lepidocyclina antiguensis* Vaughan and Cole in Vaughan, *idem*, p. 19, 20, pl. 10, fig. 8; pl. 24, figs. 2, 3.

1933. *Lepidocyclina (Lepidocyclina) giraudi* R. Douvillé, Vaughan, *idem*, p. 20, 21, pl. 10, figs. 9, 10; pl. 24, fig. 4.

1944. *Lepidocyclina (Lepidocyclina) parvula* Cushman, Cole, Florida Geol. Survey, Bull. 26, p. 72, 73, pl. 3, fig. 4; pl. 19, figs. 1, 2, 7; pl. 20, figs. 1, 2; pl. 22, figs. 1-11.

1953. *Lepidocyclina (Lepidocyclina) parvula* Cushman, Cole, U. S. Geol. Survey, Prof. Paper 244, p. 20, pl. 15, figs. 6-10.

1953. *Lepidocyclina (Lepidocyclina) parvula* Cushman, Cole, Journ. Paleont., v. 27, No. 3, p. 335, 336, pl. 44, figs. 11, 12.

Occurrence.—Widespread in the Caribbean Oligocene; Florida in the Marianna and Suwannee limestones; Mexico in the Meson formation; Antigua in the Antigua formation; Panama in the Caimito formation and the La Boca member of the Panama formation; Trinidad; Jamaica, B.W.I.; Martinique.

Remarks.—The types of this species are from Martinique, French West Indies, where it occurs in association with *Spiroclypeus bullbrooki* Vaughan and Cole. It was reported later from Trinidad (Vaughan and Cole, 1941, p. 71) also in association with *S. bullbrooki* and other species of larger Foraminifera including *Heterostegina antillea* and *L. (N.) tournoueri.*

Vaughan (1933, p. 21) discussed this species stating "*L. giraudi* represents an extreme development of the costulation of the surface. *L. canellei* without pillars and with very small papillae, stands at one end of the series; *L. parvula* occupies an intermediate position with gradation toward *L. giraudi* which stands at the other end of the series."

Although Vaughan recognized the relationship between the heavy costulate specimens (*L. giraudi*) and those with papillae (*L. parvula*), he was inclined to over emphasize the importance of surface sculpture in the recognition of species. This is demonstrated in the remarks under the species *L. antiguensis* Vaughan and Cole (in Vaughan, 1933, p. 20) where he wrote "The general aspect of *L. antiguensis* is somewhat like that of *L. giraudi* R. Douvillé. The costae in *L. antiguensis*, except at the margin of the apical area, are broad and low and become obsolete at the inner edge of the marginal rim. The costae in *L. giraudi* are more numerous, more trenchantly developed, and extend to the edge of the test." Internally, *L. antiguensis* is identical to *L. giraudi* and *L. parvula,* and the external sculpture is intermediate between the types of *L. giraudi* and *L. parvula.*

The degree of development of pillars, papillae, and surface costulation are individual rather than specific characters. This is shown, not only by the *L. giraudi-L. parvula* series, but also by the *L. yurnagunensis-L. yurnagunensis morganopsis* series. The varietal name *morganopsis* should be suppressed.

Lepidocyclina (Lepidocyclina) waylandvaughani Cole Pl. 1, fig. 6; Pl. 2, figs. 2-5, 7-9; Pl. 4, figs. 2, 5; Pl. 5, fig. 4; Pl. 6, fig. 8

1928. *Lepidocyclina (Lepidocyclina) waylandvaughani* Cole, Bull. Amer. Paleont., v. 14, No. 53, p. 21, 22, pl. 4, figs. 1-8.

1942. *Lepidocyclina (Lepidocyclina) californica* Schenck and Childs, Stanford Univ. Publ., Geol. Sci., v. 3, No. 2, p. 1-59, pls. 1-4.

1953. *Lepidocyclina (Lepidocyclina) waylandvaughani* Cole, Cole, U. S. Geol. Survey, Prof. Paper 244, p. 20-22, pl. 18, figs. 1-10, 16, 17.

1953. *Lepidocyclina (Lepidocyclina) waylandvaughani* Cole, Cole, Journ. Paleont., v. 27, No. 3, p. 336, pl. 44, figs. 13, 14.

Occurrence.—Meson formation of the Tampico Embayment, Mexico; Antigua formation of Antigua, B.W.I.; Bohio formation, the Quebrancha limestone member of the Caimito formation and the Culebra formation, Panama; Cipero marl formation of Trinidad, B.W.I.; Vaqueros formation of California (as *L. (L.) californica.*)

Remarks.—This species differs from *L. (L.) mantelli* in having lateral chambers with open cavities between relatively thin roofs and floors. It is probably derived from *L. (L.) mantelli* by a reduction in the thickness of the floors and roofs of the lateral chambers.

Specimens assigned to *L. (L.) giraudi* have thicker roofs and walls and less open cavities to the lateral chambers. Although the development of pillars is an individual rather than a specific character, specimens of *L. (L.) giraudi* consistently have pillars better developed and more evenly distributed through their tests than do specimens of *L. (L.) waylandvaughani.*

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PLATES

EXPLANATION OF PLATE 1

Figure Page

1-5, 7-9. **Lepidocyclina (Lepidocyclina) mantelli** (Morton) 38

All views are vertical sections.

1, 8. Views of the same specimen to illustrate small pillars and slit-like cavities of the lateral chambers; 1, x 40; 8, x 20; from the Marianna limestone on the Chipola River, one-half mile east of Marianna, Fla.

2, 7. Views of the same topotype, representing specimens previously called *L. (L.) supera*, to illustrate lateral chambers with thick roofs and floors and slightly arched openings; 2, x 40; 7, x 20; Byram marl, National Cemetery, Vicksburg, Miss.

3. Specimen previously called *L. (L.) supera* which is intermediate between the specimens illustrated as figures 1 and 2; x 40; Robinson's quarry, 4 miles east of Brandon, Miss., USGS loc. 6548.

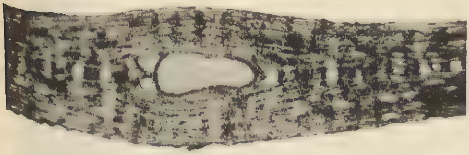
4. Specimen previously called *L. (L.) supera* which is similar to figure 1; x 40; near Duncan Church, Washington County, Fla.

5. Specimen which is similar to figure 2; x 40; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.

9. Specimen previously identified as *L. (L.) supera*; x 20; V-296, Vale Royal-Hampshire Road, Trelawny, Jamaica, B.W.I., collected by H. R. Versey.

6. **Lepidocyclina (Lepidocyclina) waylandvaughani** Cole 42

The lateral chambers have open, rectangular cavities with thin roofs and floors; x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.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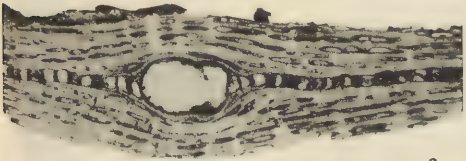
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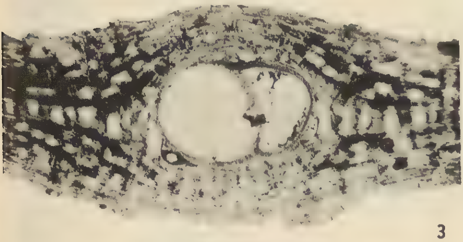
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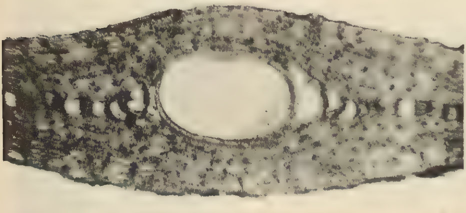
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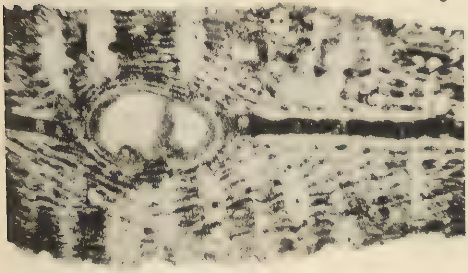
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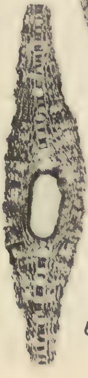
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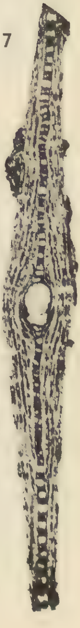
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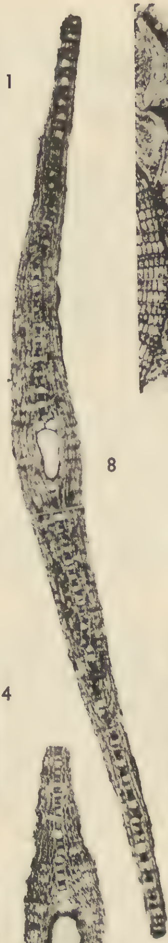
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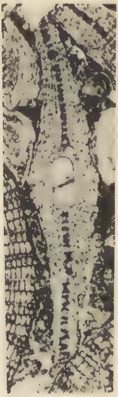
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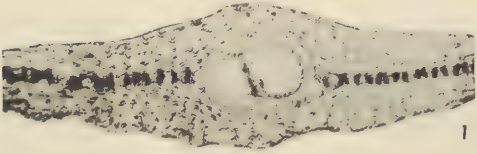

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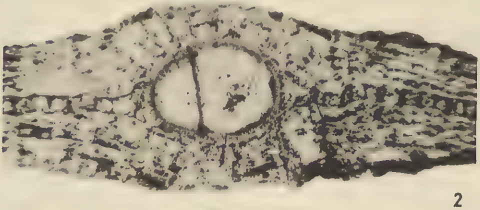

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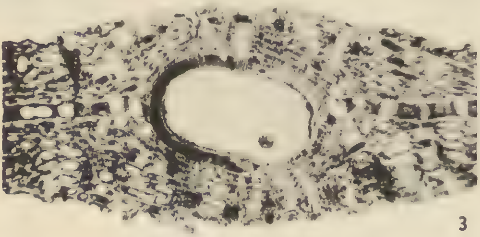

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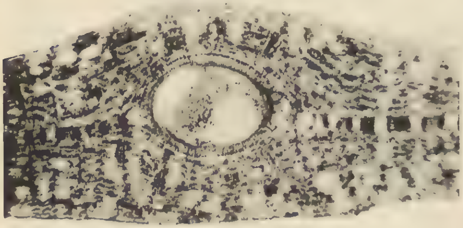

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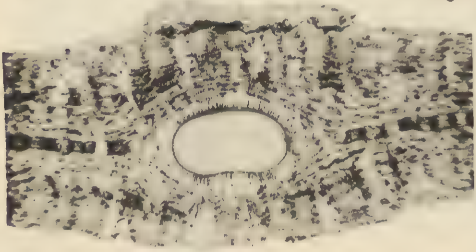

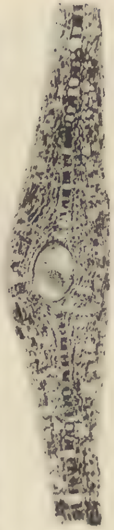

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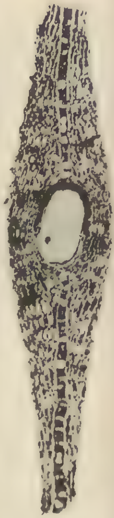

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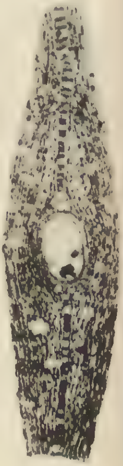


EXPLANATION OF PLATE 2

Figure		Page
1, 6.	**Lepidocyclina (Lepidocyclina) mantelli** (Morton)	38
	All views are vertical sections. 1. Specimen illustrated as figure 9, Plate 1, enlarged; x 40. 6. Specimen similar to topotypes of *L. (L.) supera*; x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.	
2-5, 7-9.	**Lepidocyclina (Lepidocyclina) waylandvaughani** Cole	42
	All views are vertical sections to show variation between individuals all of which have open, rectangular cavities to the lateral chambers between thin roofs and floors. 2. x 40; 500 meters east of Rancho Abajo which is near kilometer 9 on the Huasteca Petroleum Company's narrow gauge railroad between San Geronimo and Cerro Azul, Tampico embayment area, Mexico. 3, 9. The same specimen; 3, x 40; 9, x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I. 4, 8. The same specimen; 4, x 40; 8, x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I. 5. Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.; x 20. 7. x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.	

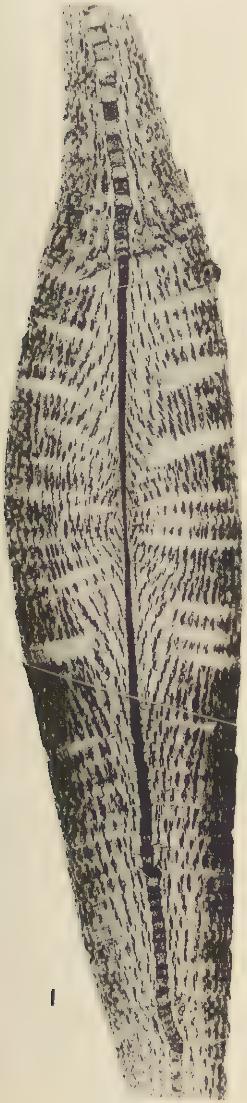
EXPLANATION OF PLATE 3

Figure Page

1-4. **Lepidocyclina (Lepidocyclina) mantelli** (Morton) 38

All views are vertical sections of microspheric specimens, x 20, to show variation between individuals.

1. Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.
2. Byram marl, National Cemetery, Vicksburg, Miss.
3. Robinson's quarry, 4 miles east of Brandon, Miss.
4. Marianna limestone on the Chipola River, one-half mile east of Marianna, Fla.



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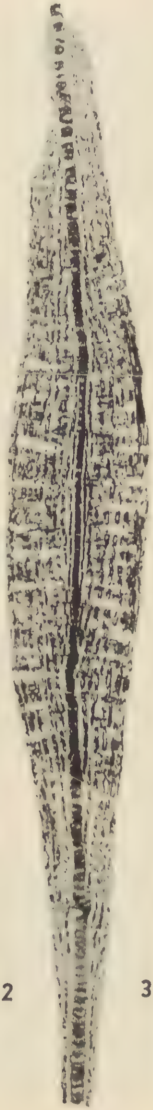

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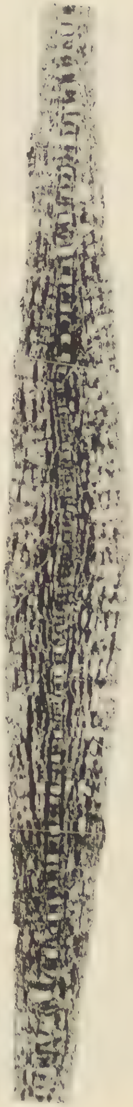

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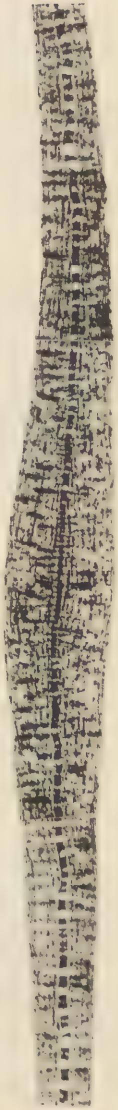

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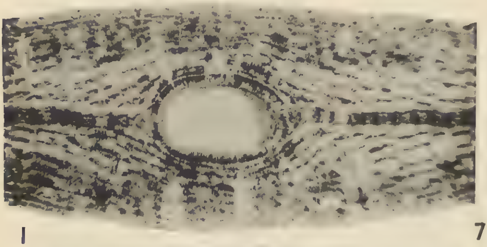

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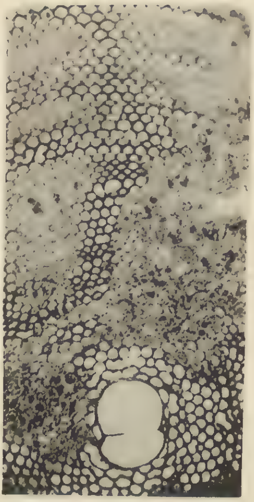

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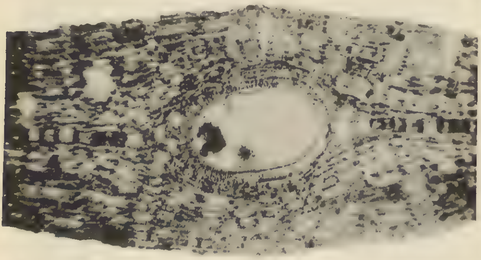

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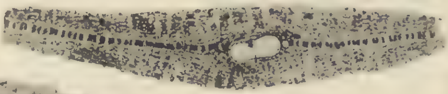

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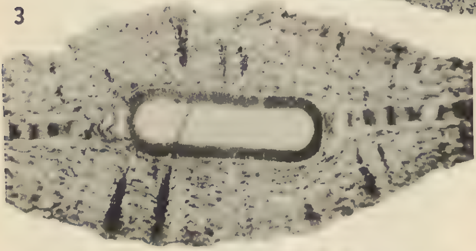

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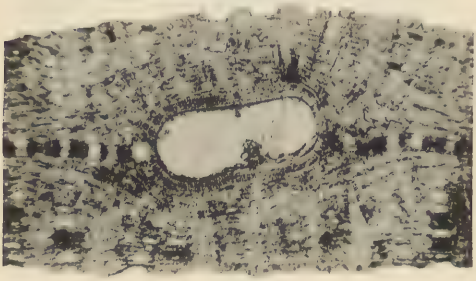

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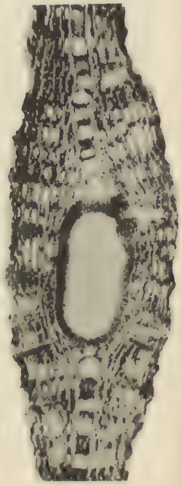

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EXPLANATION OF PLATE 4

Figure Page

1, 4, 6, 7. **Lepidocyclina (Lepidocyclina) mantelli** (Morton) 38

1. Same specimen, x 40, illustrated as figure 6, Plate 2.

4, 6. Specimen to illustrate individual variation; 4, x 40; 6, x 12.5; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.

7. Part of an equatorial section, x 20; Marianna limestone on the Chipola River, one-half mile east of Marianna, Fla.

2, 5. **Lepidocyclina (Lepidocyclina) waylandvaughani** Cole 42

2. Same specimen, x 40, illustrated as figure 7, Plate 2.

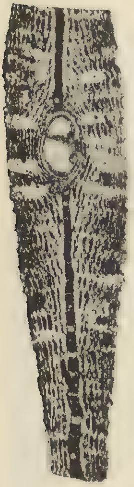
5. Same specimen, x 40, illustrated as figure 6, Plate 1.

3. **Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé 41

Enlargement, x 40, of part of figure 2, Plate 6; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.

EXPLANATION OF PLATE 5

Figure		Page
1, 2.	**Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé	41
	1, 2. Vertical sections; 1, x 20; 2, x 12.5; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.	
3, 5.	**Lepidocyclina (Lepidocyclina) mantelli** (Morton)	38
	3. Same specimen, x 20, illustrated as figure 5, Plate 1.	
	5. Part of an equatorial section, x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.	
4.	**Lepidocyclina (Lepidocyclina) waylandvaughani** Cole	42
	Part of an equatorial section, x 20; 500 meters east of Rancho Abajo which is near kilometer 9 on the Huasteca Petroleum Company's narrow gauge railroad between San Geronimo and Cerro Azul, Tampico embayment area, Mexico.	
6, 7.	**Amphistegina bullbrooki** (Vaughan and Cole)	37
	6. Transverse section, x 20, to illustrate the slight asymmetry of the test; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.	
	7. Median section, x 20, from the same locality as figure 6.	



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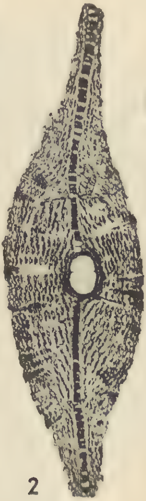

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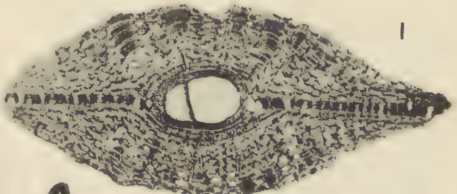

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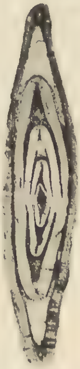

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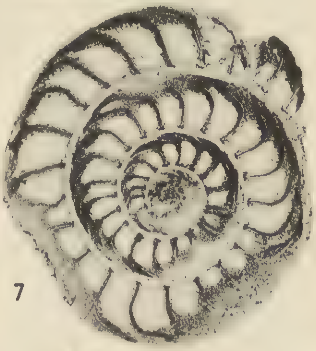

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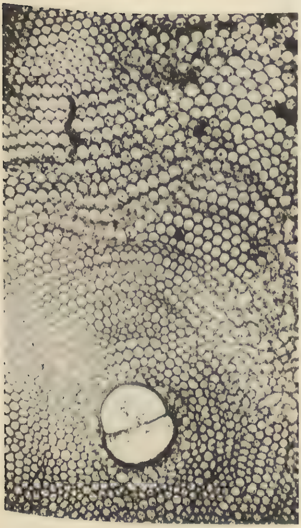

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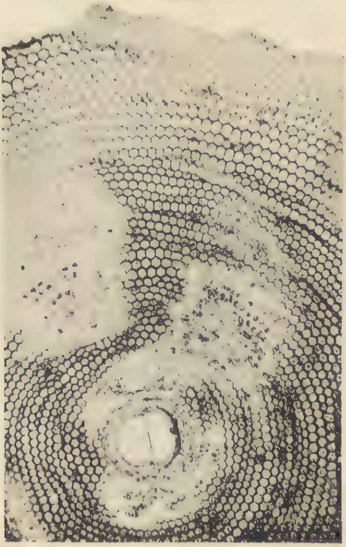

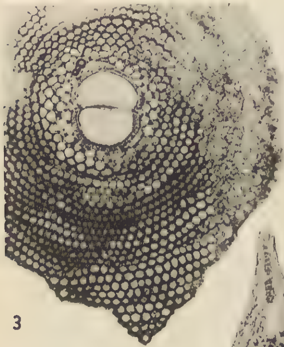

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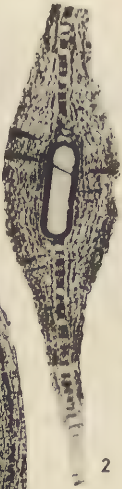

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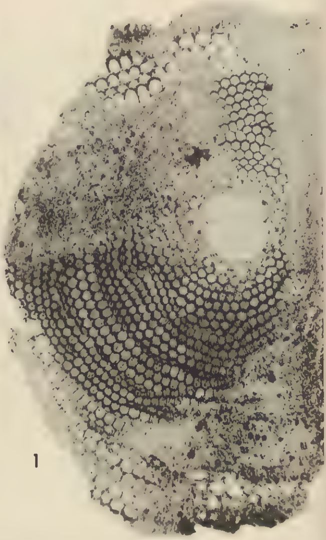

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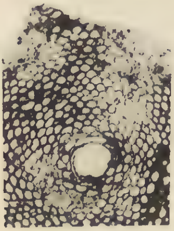

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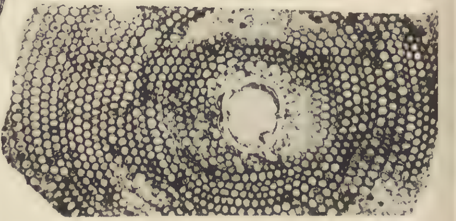

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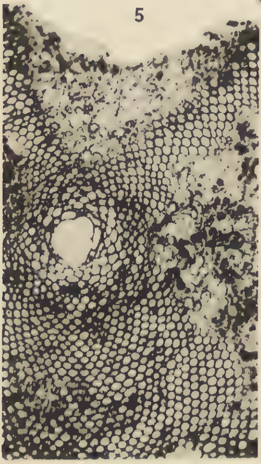

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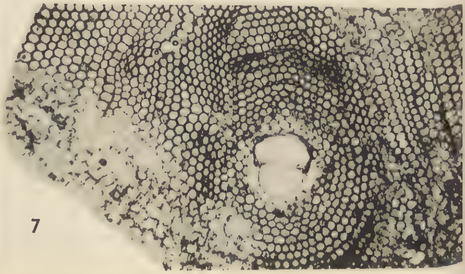

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EXPLANATION OF PLATE 6

Figure Page

1, 2. **Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé 41

1. Equatorial section, x 20, of a specimen similar in external appearance and from the same locality as the specimens illustrated as figures 1, 2, Plate 5.

2. Vertical section, x 20, of a specimen with large embryonic chambers; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.

3-7. **Lepidocyclina (Lepidocyclina) mantelli** (Morton) 38

3. Equatorial section, x 20, of a specimen similar in external appearance and from the same locality as figure 2.

4, 5. Parts of equatorial sections, x 20, of topotypes of *L. (L.) supera;* Byram marl, National Cemetery, Vicksburg, Miss.

6. Vertical section, x 12.5, of a small, lenticular microspheric specimen; Robinson's quarry, 4 miles east of Brandon, Miss., USGS loc. 6548.

7. Part of an equatorial section, x 20; Kugler loc. 11398, Morne Diablo quarry, Trinidad, B.W.I.

8. **Lepidocyclina (Lepidocyclina) waylandvaughani** Cole 42

Part of an equatorial section, x 20, of a specimen similar in external appearance and from the same locality as figure 4, Plate 2.

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THE OSTRACODA OF THE YORKTOWN FORMATION IN THE YORK-JAMES PENINSULA OF VIRGINIA

(With notes on the collection made by Denise Mongin from the area)

By

JAMES D. MCLEAN, JR.

July 16, 1957

Paleontological Research Institution
Ithaca, New York, U.S.A.

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THE OSTRACODA OF THE YORKTOWN FORMATION IN THE YORK-JAMES PENINSULA OF VIRGINIA

(WITH NOTES ON THE COLLECTION MADE BY DENISE MONGIN FROM THE AREA)

JAMES D. MCLEAN, JR.

ABSTRACT

Thirty species of Ostracoda from the Yorktown formation and lower beds in the York-James Peninsula of Virginia are described; one species, *Murrayina barclayi,* is new. The combined ostracode-foraminiferal assemblage of the Yorktown seems to be closer to the *Ecphora-Cancellaria* facies of the Choctawhatchee formation of Florida, than to any other fauna.

A collection of Mollusca, Foraminifera, and Ostracoda made by Dr. Denise Mongin is tabulated and discussed in terms of Mansfield's two Yorktown zones, and the fauna of the Powell's Lake, Virginia, outcrop is confirmed in its St. Marys age by the mollusk identifications of Mongin.

GENERAL BACKGROUND

The study is an extension of the author's foraminiferal one (McLean, 1956) and was undertaken because the ostracode fauna was so strikingly developed in the Yorktown formation, that to ignore it would have been equivalent to leaving a job half done. The author tried without success to interest an ostracode specialist in the project; the result was that it was necessary to attempt the study alone, which was done with the generous assistance of Dr. Henry V. Howe.

I would like to stress that this study is by no means complete. In the first place, picking of Ostracoda was not the primary interest of the author, hence the earlier samples (on which much of the foraminiferal paper is based) did not include slides of Ostracoda. Secondly, in my obvious unfamiliarity with Ostracoda, it is possible that I have overlooked some forms, although I tried to acquire as complete a collection as possible. Thirdly, I am convinced that the shifting environments of the Yorktown formation are more extensive than first believed, and it appears that the Ostracoda in particular may be represented in other samples by species that neither I nor Dr. Doris Malkin Curtis have yet encountered. This, I believe, will be even more true of the Ostracoda than is the case with the Foraminifera.

The collections of Dr. Denise Mongin of the Institut Catholique, Paris, are of special interest. They serve as an interesting check of the material collected by me, and confirm certain points that my material could only suggest. Any collection comprising 123 species of animals would be of considerable comparison value but what makes the Mongin collection more important is that it was done at a time when erosion damage to the Yorktown formation outcrops had exposed material to which I originally had no access. This exposure gave us an interesting bed of *Pecten clintonius* at Carter's Grove, Virginia, which completely confirmed the fact that here we have all three major divisions of the Yorktown as originally set up by Mansfield and his cohorts.

I do not believe Mansfield's zones are stratigraphically valid; the microfaunas rather suggest that these "zones" are ecological in nature. The basal portion of the Yorktown (at Carter's Grove) does indeed seem to contain an "older" fauna than the upper portion of the Carter's Grove outcrop and those of the York River side, if we may believe that the present state of knowledge is such as to permit us to say that these are indeed "older" assemblages. I prefer to reserve judgment on the validity of Yorktown "zones" until more can be known about the ecological situations involved. The Ostracoda give little on which to "zone" with.

On the other hand, 11 of the 30 species of Ostracoda here studied are apparently limited to the Yorktown and equivalent beds, and five other species seem to be limited to the pre-Yorktown. I have been informed by Philip Brown (personal communication) that the North Carolina ostracode situation may be negative to the results obtained by Dr. Malkin and myself (who are so far the only serious workers on Virginia Yorktown Ostracoda), so this must be considered in application of these results.

Notwithstanding my own reservations about the Mansfield zonations, I have used these "zones" as a method of separation for tabulation and discussion purposes. The reason for this action is that most students of the Yorktown are familiar with the Mansfield concept and some still accept it as valid. The fact remains that the Yorktown could have been easily separated into other "zones" and that some of them might prove considerably more significant statistically. However, I am afraid that the significance of statistical conclusions as drawn from data to hand would again be more apparent than real. In erecting statistical criteria, one must first inquire as to the completeness of data; in the case of the Yorktown formation, the evidence of shifting environments is too strong to allow one to put much faith in such statistical conclusions as might be drawn.

ACKNOWLEDGMENTS

The reader is referred to the foraminiferal part of this report for the acknowledgments to many of the people involved; their services as enumerated there (McLean, 1956, p. 263) equally apply to the present paper which is but a continuation of the first part. The National Science Foundation allowed an extension of the Grant for illustrations for this ostracode paper; Dr. Katherine V. W. Palmer, Mrs. Archibald McCrea, Mrs. Edna Dove, the author's parents, and others have all continued the assistance previously acknowledged. Mrs. Sally D. Kaicher illustrated the Ostracoda in her usual superb manner.

Dr. Henry V. Howe of Louisiana State University most generously assisted the author by reviewing the preliminary taxonomic notes of this study and the finished manuscript, and thereby prevented many errors of identification and classification. There may be errors, but they must be imputed to the author, who is the only one responsible for them.

Dr. Denise Mongin is owed the author's thanks for allowing use of her mollusk lists and her stratigraphic notes on these forms. I take full reponsibility for the stratigraphic conclusions, for the views set forth in this paper are based upon data and considerations not available to Dr. Mongin; her conclusions were, however, most helpful.

DEPOSITION OF SPECIES

All Ostracoda collected by the author are deposited at the Paleontological Research Institution, Ithaca, New York, and are listed under P. R. I. numbers 22,486 to 22,645 inclusive. The material listed in the Mongin collections (mollusks, Foraminifera, and Ostracoda) are deposited in the collections of the Laboratoire de Geologie, Institut Catholique, 21 Rue d'Assas, Paris (6) France, where they may be studied by obtaining the permission of Dr. Denise Mongin or Dr. A. F. de Lapparent.

COMMENTS ON THE CHOCTAWHATCHEE AS CORRELATED WITH THE YORKTOWN FORMATION

The closest correlation of the Foraminifera (McLean, 1956) and Ostracoda of the Yorktown formation is with the Choctawhatchee formation of Florida. Since more is known of the Florida Choctawhatchee than is known of the Duplin marl or other possible equivalent faunas, this close correlation may be more apparent than real.

COMPARISON OF YORKTOWN OSTRACODE FAUNA

WITH OTHER RECORDED MIOCENE FAUNAS.

NOTES:
(1) Yoldia facies (Puri 1954)
(2) Arca facies (Puri 1954)
(3) Ecphora facies (Puri 1954)
(4) Cancellaria facies (Puri 1954)
(5) The pre-Yorktownian ranges are from data by the author and from the following sources: Puri (1954); Ulrich and Bassler (1904); Malkin (1953).

	YORKTOWN ZONE II	YORKTOWN ZONE I	CHOCTAWHATCHEE (1)	CHOCTAWHATCHEE (2)	CHOCTAWHATCHEE (3)	CHOCTAWHATCHEE (4)	MALKIN'S YORKTOWN	EDWARD'S DUPLIN	PRE-YORKTOWN (5)
Bairdoppilata triangulata	▬	▬			▬	▬		▬	▬
Paracypris choctawhatcheensis	▬	▬			▬	▬			
Cytheromorpha cf. warneri	▬				▬	▬	▬		▬
Loxoconcha purisubrhomboidea	▬	▬			▬	▬	▬	▬	
Loxoconcha reticularis					▬	▬		▬	▬
Cytheropteron talquinensis	▬	▬			▬	▬			
Cytherura reticulata		▬					▬	▬	
Clithrocytheridea diagonalis									▬
Clithrocytheridea virginiensis	▬	▬					▬		
Paracytheridea vandenboldi		▬		▬			▬		
Eucythere sp.	▬	▬							
Cushmanidea ashermani	▬	▬	▬	▬	▬	▬	▬		▬
Cushmanidea echolsae	▬						▬		
Cushmanidea ulrichi	▬	▬	▬	▬			▬		
Leguminocythereis cf. whitei							▬		▬
Pterygocythereis americana	▬	▬		▬	▬	▬	▬		▬
Actinocythereis exanthemata	▬	▬	▬	▬	▬				▬
A. exanthemata gomillionensis	▬	▬		▬	▬	▬	▬	▬	
Echinocythereis clarkana									▬
Murrayina howei				▬			▬		▬
Murrayina martini	▬	▬		▬	▬	▬	▬		▬
Murrayina barclayi	▬	▬							
Orionina vaughani	▬	▬		▬	▬	▬	▬	▬	▬
Puriana rugipunctata	▬	▬	▬	▬	▬	▬	▬	▬	▬
Acuticythereis laevissima	▬	▬					▬	▬	▬
Cytheretta burnsi	▬	▬		▬	▬	▬	▬		▬
Cytheretta ulrichi	▬	▬					▬		▬
Hemicythere schmidtae	▬	▬					▬		
Aurilia conradi	▬	▬		▬	▬	▬	▬	▬	▬
Cytherella chipolensis									▬

However, it is of interest to note that there is a statistical relationship between Choctawhatchee Foraminifera and Ostracoda and those of the Yorktown formation that is closer than that of any other recorded Miocene fauna in the Atlantic region. In the case of the foraminiferal study (McLean, 1956) I did not feel justified in placing any great emphasis on this relationship, as I believed the evidence too inconclusive and incomplete to note any trend or real relationship. However, in considering both the foraminiferal record in my last paper, and the ostracode record as here developed, it appears that a definite trend emerges which is worthy of notice.

Not only is the record still in favor of a Choctawhatchee-Yorktown relationship, but the relationship may be said to be between the *Ecphora-Cancellaria* "facies" of the Choctawhatchee and the Yorktown fauna, a significant narrowing of the stratigraphic and/or ecologic boundaries. Therefore, it is important to consider the signficance of the *Ecphora-Cancellaria* "facies" in terms of the Yorktown formation.

The older references, such as the Mansfield and Cushman and Ponton Miocene publications on the Choctawhatchee formation regarded the *Yoldia, Arca, Ecphora,* and *Cancellaria* assemblages as "zones". Later authors, such as Puri and Vernon, experienced difficulty in tracing these "zones", and, as developed by Puri (1954) the concept has grown that these assemblages are of facies rather than zonal significance. It may be added that at least one mollusk worker has told me that he still feels there is reason to regard these same assemblages as valid zones.

It is my opinion, based upon growing ecological data, that Puri and his cohorts have the better viewpoint. It is clear that ecological differences can be mistaken for stratigraphic ones, since the difference between contemporary ecologies of different environmental settings is so pronounced that the faunas, if encountered in the subsurface, would be ascribed to different formations or zones.

Puri (1954, p. 40-41) said the following:

"Sediments referred to *Arca* facies were deposited off shore under outer neritic conditions. These sediments are mostly gray, sandy shell marls. *Arca* facies in its lower portion is contemporaneous with the *Yoldia* facies but the upper portion is contemporaneous with the *Cancellaria* facies.

"*Ecphora* facies was deposited under conditions similar to those of the *Arca* facies but the fauna is from deeper water. The sediments consist of shell marls deposited during the regression of the Choctawhatchee sea. The succeeding advance of the Choctawhatchee sea deposited the *Cancellaria* facies.

"*Cancellaria* facies is in part contemporaneous with the *Arca* and *Ecphora* facies and in part younger. The only known occurrence where the *Cancellaria* facies is known to overlie the *Ecphora* facies is in the vicinity of Jackson Bluff."

Puri's characterization of these facies is quite similar sedimentationally to observed Yorktownian conditions. He characterized the *Arca, Ecphora,* and *Cancellaria* facies as progressively deeper from *Arca* to *Cancellaria,* and these three facies were called by him "outer neritic" as opposed to the inner neritic, muddy-bottom, *Yoldia* facies. (Puri, 1954, pp. 49-51). I have not here repeated his observations on the *Yoldia* facies in detail, because the Yorktown faunas do not show an assemblage analogous to this facies. According to Puri's chart on page 15, the *Yoldia* and *Arca* facies are the updip equivalents of the downdip *Ecphora* and *Cancellaria* facies, with the *Yoldia* and *Ecphora* facies being basal respectively to the *Arca* and *Cancellaria* facies.

The depths of Puri's facies may be somewhat deeper than is the case with some of the Yorktown outcrops, but by no means entirely so ; these depth fluctuations in the Yorktown formation are to be expected, and should not be considered as negating the essential facies equivalencies between the Yorktown formation and the *Ecphora-Cancellaria* facies of the Choctawhatchee formation.

The total faunas of the Yorktown and the two Choctawhatchee facies reveal that there are more species not common to the two formations than are common. These divergences may be provincial, climatic, or ecologic, and probably arise from a combination of these factors plus others as yet unknown. I do not think the difference is stratigraphic; indeed, I believe that study of the Miocene sediments between Florida and Virginia will eventually reveal a slowly changing fauna from the Yorktown of Virginia to the Choctawhatchee of Florida with environmental controls determining the transition from the one fauna to the other.

I find, however, that the ostracode fauna of the Duplin marl of North Carolina shows disappointingly few species in common with the Virginia Yorktown, and the Duplin ostracode fauna was fairly completely described by Edwards. Only three species seem to be restricted to the Yorktown, Duplin, and Choctawhatchee formations and not ranging into the Pre-Yorktownian. The remaining six species common to the Yorktown and the Duplin also range into the Pre-Yorktown and cannot be regarded as guides for the uppermost Miocene.

This would indicate that the majority of the Yorktown Ostracoda are too long-ranging stratigraphically to be of much value as zonal guide species, since a number of them are rare and may have been overlooked in older sediments. Their potential value as ecological indices may be considerable, but as Malkin indicated (1953, p. 772), more work must be done to narrow the ecologies of modern Ostracoda before fossil ones can be properly evaluated.

Malkin made the following observations about Yorktown Ostracoda: (Malkin, 1953, p. 772) ". . . The Yorktownian ecology, on the other hand, encouraged the existence of an abundant and varied fauna that indicates normal continental shelf environment. The presence in the Yorktownian of abundant relatively smooth forms, compared with the predominance of tuberculate forms in the Calvertian, may indicate more open sea conditions for the Yorktownian deposits . . . ."

All of the fossil evidence so far presented, therefore, seems to agree on the open-sea environment for the Yorktown formation, in relatively shallow waters. I should add that Malkin's Yorktown fauna and that collected for this study involve a number of species not common to our respective collections. The difference is rather startling, but it stems in great part from the differences of samples, as I have noted a great difference in ostracode assemblies from sample to sample; certainly this study cannot be said to be based on inadequate samples, as my samples were both numerous and large.

The Yorktown formation is one of shifting environments; such shifting involves differentiation of faunas from locality to locality and from level to level. It would, therefore, require great numbers of samples of large size to arrive at a "representative fauna" for the Yorktown. While the fauna is excellently preserved, I have found it necessary to wash and float large quantities of material to get good representative assemblages of Foraminifera and Ostracoda. If Dr. Malkin notes with surprise that some species she found numerous in her Yorktown material are not included here, I can add that I was equally surprised to find species of common occurrence in my material not mentioned by her in her study. I would be inclined to think that this difference is not due to lack of study or sampling by either of us—but rather to the environmental differences of the Yorktown beds.

THE COLLECTIONS OF DR. DENISE MONGIN

In the spring of 1955, Dr. Denise Mongin of the Laboratoire de Geologie, Institut Catholique, Paris, France, went with the author on a collecting trip in the Yorktown formation outcrop area. The localities were markedly modified by erosion since the author's previous trips (mainly from hurricane damage). Dr. Mongin visited an outcrop at the Moore House Beach, Virginia, unaccessible to the author on the original collection trips.

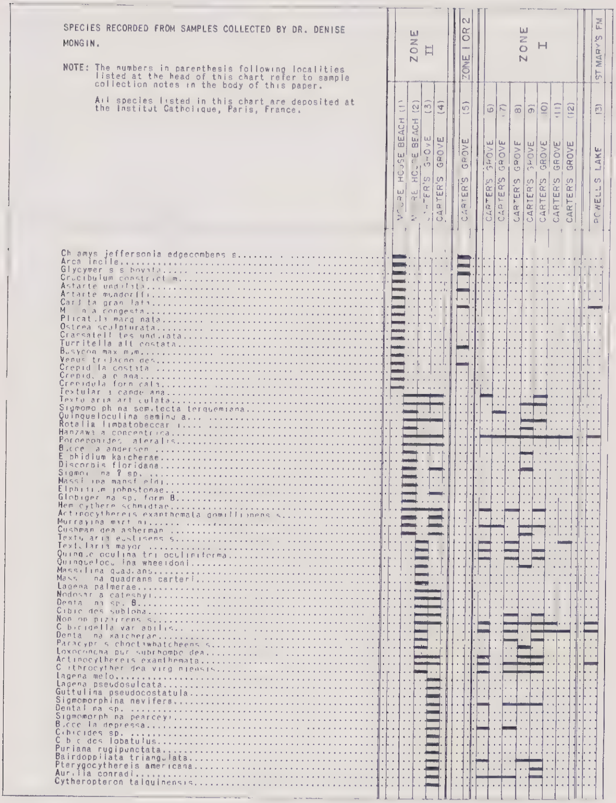
The material from Dr. Mongin's collections was first isolated from mollusks and sent to the author for microfossil examination. The tables above contain the results of these labors, covering the macrofossils (identified by Mongin) and the microfossils identified by the author. Results are summarized below, under the labels as furnished by Dr. Mongin. The numerical order of treatment corresponds with the numbers on the charts.

(1) "Fossils collected at Moore House Beach, (*Chlamys* and *Venus* beds)."

Of the listed fossils, three are restricted to Zone II of the Yorktown, six others are restricted to the Yorktown formation, and the rest have longer ranges.

(2) "*Chlamys* bed, Moore House Beach"

The sand furnished under this label is a Yorktown Zone II aggregation and was separated from (1) above only because the label restricts it more than the above list of fossils.



SPECIES RECORDED FROM SAMPLES COLLECTED BY DR. DENISE MONGIN.

NOTE: The numbers in parenthesis following localities listed at the head of this chart refer to sample collection notes in the body of this paper.

All species listed in this chart are deposited at the Institut Catholique, Paris, France.

(3) "Carter's Grove, top *Chama* bed"

This assemblage also is Zone II from the microfossil evidence. It is the uppermost *Chama* bed at Carter's Grove and not the basal one that Mansfield noted at the base of Zone II.

(4) "Carter's Grove (*Chama* bed), lower bed"

This is the basal *Chama* bed of Mansfield and the bed at six feet above the cliff of McLean (1956). As Mansfield designated it, this is the base of Zone II.

SPECIES RECORDED FROM SAMPLES COLLECTED BY DR. DENISE MONGIN. (PART II)

	ZONE II				ZONE I OR 2	ZONE I							ST MARY'S FM
	MOORE HOUSE BEACH (1)	MOORE HOUSE BEACH (2)	CARTER'S GROVE (3)	CARTER'S GROVE (4)	CARTER'S GROVE (5)	CARTER'S GROVE (6)	CARTER'S GROVE (7)	CARTER'S GROVE (8)	CARTER'S GROVE (9)	CARTER'S GROVE (10)	CARTER'S GROVE (11)	CARTER'S GROVE (12)	POWELL'S LAKE (13)
Chlamys jeffersonia					■								
Chlamys (Placopecten) clintonia					■								
Venus rileyi					■								
Venus campechiensis tetrica					■								
Crassatellites undulatus cyclopterus					■								
Dentalium attenuatum					■								
Ostrea disparilis					■								■
Cyprocardia arata					■								
Ecphora quadricostata					■								
Spisula confraga					■								
Saxolucina anodonta					■								
Glycymeris subovata tourneyi					■								
Calliocardia subnasuta					■								
Ilyanassa harpuloides					■								
Turritella pilsbryi					■								
Chama congregata					■								
Arca centenaria					■								
Crepidula aculeata					■								
Teredo calamus					■								
Dosinia acetabula					■								
Panopea reflexa					■								
Glycymeris americana					■								
Diodora redimicula					■								
Textularia pseudoobliqua						■		■			■		
Textularia pseudoobliqua aspera						■		■				■	
Textularia gramen						■		■	■				■
Massilina marylandica						■							
Quinqueloculina sp.						■		■					
Pseudopolymorphina rutila						■		■		■			
Pseudopolymorphina sp.						■							
Guttulina austriaca						■							■
Planulina depressa						■		■			■	■	
Bulimina gracilis						■		■		■	■		■
Buccella parkerae						■		■					■
Angulogerina cf. occidentalis						■							
Cancris sagra						■		■		■			
Discorbis ? sp.						■							
Cytheretta ulrichi						■		■		■			
Murrayina barclayi						■							
Acuticythere s laevissima						■		■					
Orionina vaughani						■				■			
Cushmanidea ? sp.							■						
Globigerina sp. form E								■					
Textularia cf. badenensis								■					
Sigmomorphina sp.								■					
Cytheretta burnsi								■		■			
Globigerina sp. form A									■				
Quinqueloculina seminulangulata									■				
Textularia sp.										■			
Massilina ? sp.										■			
Robulus vaughani										■			
Nodosaria sp.										■			
Guttulina sp. A										■			
Chlamys santamaria middlesexensis													■
Chlamys eborea urbannensis													■
Chione latilirata													■
Isognomon maxillata n. var. ?													■

(5) "Carter's Grove"

This is an undifferentiated list of fossils identified by Mongin. It contains species that are variously restricted to either Zone I or Zone II, and the collection is, therefore, a composite one from both Yorktown zones of Mansfield. It is of importance in that it confirms the presence of both zones at Carter's Grove, Virginia, and because the presence of *Pecten clintonius* is confirmed for the outcrop at the base of the cliff, where for the first time an assemblage of this species was found. Previously, a single specimen, found by the author and identified by Richards, furnished the only indication that the base of the cliff at Carter's Grove corresponds to Mansfield's *Pecten clintonius* zone. A single specimen of *Turritella pilsbryi* Gardner, another important Zone I guide, was also found by Dr. Mongin; previously this species was not found there by the author.

The *Pecten clintonius* assemblage (a bed containing the species with a sandstone matrix) was evidently uncovered by hurricane erosion.

(6) "*Chlamys jeffersonia* bed, Carter's Grove"

The microfossils of this sample and of the remainder of the Carter's Grove samples (7 to 12) are all Zone I assemblages.

(7) "Carter's Grove, *Chlamys jeffersonia* bed"

(8) "Carter's Grove, *Chlamys jeffersonia* bed, Cliff base"

(9) "Carter's Grove, *Chlamys jeffersonia* bed, bottom of cliff"

Rotalia limbatobeccarii McLean is found in Zone I for the first time.

(10) "Carter's Grove, basal bed"

(11) "*Chlamys clintonia* bed, Carter's Grove, (water's edge) bottom of cliff"

One noteworthy thing about this and the following sample is that no ostracods and few Foraminifera were found associated with *Pecten clintonius*. Whether lithification or leaching is responsible is not known. The few Foraminifera found seem to indicate an ecology favorable to Ostracoda.

(12) "Between two valves of *Chlamys clintonia* (Carter's Grove)."

(13) "Powell's Lake Spillway"

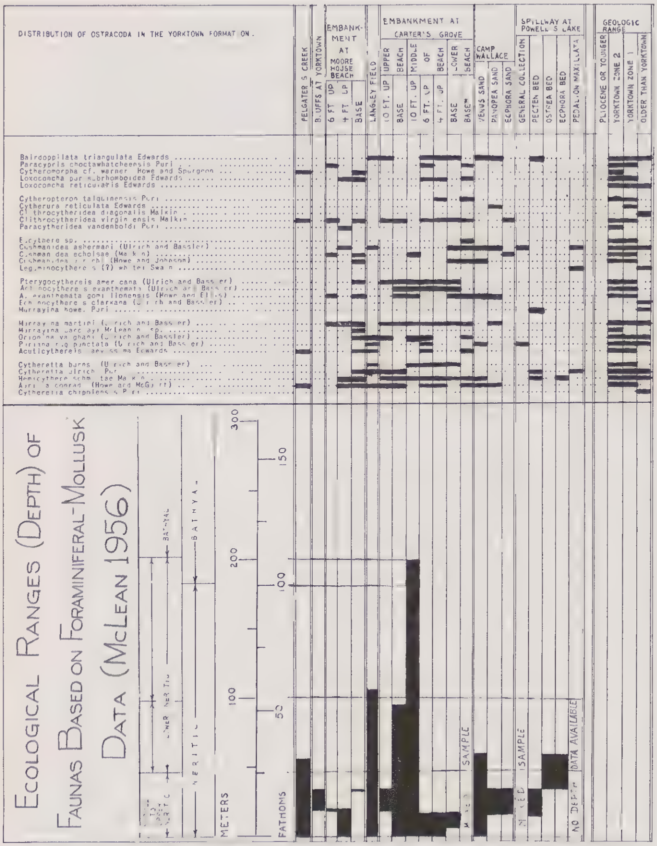


CHART SHOWING LOCALITY DATA ON OSTRACODA AND ECOLOGICAL DATA

Dr. Mongin's mollusk identifications confirm the St. Marys age of the Powell's Lake, Virginia, outcrop postulated by McLean (1956). Foraminifera and Ostracoda continued to be sparse and nondiagnostic, with no forms restricted to (or absent from) the Yorktown formation faunas. The sparsity of these forms indicates an unfavorable environment which also coincides with present ideas of the St. Marys formation.

SYSTEMATIC DESCRIPTIONS

Order **OSTRACODA** Latreille

Suborder **PODOCOPA** Sars

Family **BAIRDIIDAE**

Subfamily **BAIRDIINAE** Sars, 1923

Genus **BAIRDOPPILATA** Coryell, Sample, and Jennings, 1935

Bairdoppilata triangulata Edwards Pl. 7, figs. 1a-d

Bairdoppilata triangulata Edwards, 1944, Jour. Pal., vol. 18, p. 507, pl. 85, figs. 5-7.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 223, 225, pl. 1, figs. 3-4, text figs. 1a-b.

Carapace subtriangular in side view, right and left valves very dissimilar. Right valve subtrapezoidal, posterior margin produced in subacute beak like extension. Left valve larger, subtriangular, overlaps right valve most prominently in middle portion of ventral margin, dorsal margin strongly arched, posterior more pointed than anterior, geatest height at middle. Viewed dorsally carapace thickest in middle, tapering evenly to both ends. Surface smooth except for numerous small punctae and a low swelling in middle of each valve. Short serrate denticulations frequent on anterior and posterior ventral margins.

Hinge of left valve consists of groove along inrolled surface of dorsal margin just posterior to highest point of valve. Groove continues on under side of dorsal edge but disappears within half of total length of anterior and posterior dorsal slopes. Teeth and sockets taxodontoid 6 or 7 at each end of hinge line just dorsal to anterior and posterior angulations and underneath overlapping portion of valve. Corresponding ridge with faint groove along its dorsal edge present on dorsal margin of right valve. Left dorsal edge of this valve fits into groove of dorsal slope, bears at each end of this slope taxodontoid teeth fitting into those of other valve. Muscle scars ten, irregularly rounded, in circular group just below center of valve, two more located just below and behind this group and a few others located above and before primary area.

Two forms, one higher than the other; may represent the sexes, possibly the higher is female. (Edwards, 1944.)

Dimensions.—Length, 0.72-0.83 mm.; height, 0.48-0.52 mm. Holotype, 0.81 mm., long, 0.49 mm., high.

Occurrence.—Carter's Grove, bank base, lower beach, four and six feet up bank, midbeach, 10 feet up bank on upper part of beach; Langley Field house excavation; Camp Wallace; Powell's Lake Spillway.

Remarks.—Specimens from the Yorktown formation seem typical of Edwards' form except that the muscle scars were not observed in open valves, and most specimens from the Yorktown are still articulated.

Family **CYPRIDAE**

Genus **PARACYPRIS** Sars, 1866

Paracypris choctawhatcheensis Puri Pl. 7, figs. 2a-d

Paracypris choctawhatcheensis Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 227-228, pl. 1, figs. 10-12, text figs. 2a, b, d.

Carapace large, elongate, two and a half to three to one. Dorsal margin arched; ventral margin gently concave. Anterior end oblique in the upper half; broadly rounded in the lower half. Posterior end sharply angular. Surface of the carapace smooth. Viewed from inside, the valves are moderately deep. Anterior margin broad with long, broadly spaced, bifurcating, marginal pore canals. Posterior margin narrow, with ten to twelve radial pore canals. Hinge normal to the genus. There is a well-pronounced projecting flange in front of the hinge line in the left valve. (Puri, 1954).

Dimensions given.—Length, 0.963 to 1.030 mm.; height, 0.338 to 0.422 mm.

Occurrence.—Rare. Carter's Grove, midbeach, six feet up bank; Carter's Grove base of bank; Moore House Beach, six feet up the bank.

Remarks.—Opened valves of this form do not seem to show the pore canals mentioned by Puri, but otherwise the forms from the Yorktown are identical with his species.

Family **Cytheridae**

Subfamily **LOXOCONCHINAE** Sars, 1926

Genus **CYTHEROMORPHA** Hirschmann, 1909

Cytheromorpha cf. **warneri** Howe and Spurgeon Pl. 7, figs. 3a-b

Cytheromorpha warneri Howe and Spurgeon, 1935, Howe *et al.* Florida Geol. Sur., Bull. 13, pp. 11-12, pl. 2, figs. 5, 8-9, pl. 4, fig. 4.; Swain, 1951, (*C.* cf. *warneri*) U. S. Geol. Sur., Prof. Paper 234-A, p. 49, pl. 7, figs. 18-19; Malkin, 1953, Jour. Pal., vol. 27, p. 787, pl. 80, figs. 18-19.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 277, pl. 6, figs. 5-7, text figs. 11f-g.

Carapace oblong ovate in outline, the males being more elongate than the females. Dorsal and ventral margins are nearly straight and converge gently toward the posterior, the upper third of the anterior end is obliquely truncate, the remainder regularly rounded; the upper two-thirds of the narrower posterior end is obliquely truncate, the lower one-third rounded so as to form an obscure angulation below the middle. Greatest height at the anterior cardinal angle, thickness approximately equal throughout most of the length; surface finely and regularly reticulate, the reticulations being roughly hexagonal in outline and arranged in rows more or less parallel to the margins. There is a faint tendency to a median sulcus. Viewed from the inside, the valves are moderately shallow, shiny, translucent. The marginal area which is broad around the anterior end, narrows considerably in the middle of the ventral margin, widens again in the posterior half of the ventral margin and becomes narrower around the posterior end. The line of concrescence lies near the outer margin around the anterior end, but elsewhere coincides with the inner margin. The hinge of the right valve consists of a small, button-shaped tooth below the dorsal margin; on either side of this tooth there is a small pit for the reception of the two anterior teeth of the left valve. The dorsal margin is nearly straight and grooved for the reception of a bar in the opposite valve. The posterior cardinal angle is occupied by an oval, oblique socket which has a bulbous swelling on either side of it and a raised rim above it. The hinge of the left valve consists of an anterior socket in front of which lies a small, knob-like tooth and behind which lies the swollen anterior end of the hinge bar. The posterior cardinal angle is occupied by a small, knob-like tooth with depressions in front of and behind it. The tooth and depressions are flanked above by the raised postero-dorsal margin. The pore canals are few in number and regularly spaced around the anterior end. (Howe and Spurgeon, 1935).

Dimensions.—Length, 0.58 mm.; height, 0.30 mm.; thickness, 0.24 mm.

Occurrence.—Felgater's Creek; Moore House Beach, bank base.

Remarks.—Compared with a topotype sent the author by Howe, the ornamentation of the Yorktown specimens referred to this species is considerably weaker and may be sufficiently so to differentiate this from *C. warneri.* The Yorktown specimens consist of two badly weathered valves from two localities, and it is inadvisable to describe them as new.

Genus **LOXOCONCHA** Sars, 1866

Loxoconcha purisubrhomboidea Edwards Pl. 7, figs. 4a-e

Loxoconcha purisubrhomboidea Edwards, in Puri, 1953, Jour. Pal., vol. 27, p. 750.; Puri 1954, (1953) Florida Geol. Sur., Bull. 36, p. 274, pl. 10, fig. 8, text fig. 10h.

Loxoconcha subrhomboidea Edwards (not Brady, 1880), 1944, Jour. Pal., vol. 18, No. 6, p. 527, pl. 88, figs. 28-32.; Swain (?), 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 25, pl. 2, figs. 18-19.; Malkin, 1953, Jour. Pal., vol. 27, No.6, p. 787, and pl. 80, figs. 13-17 (figured as *L. reticularis*).

Carapace subrhomboidal. Dorsal outline slightly arched; ventral outline sinuate, concave just anterior to middle; anterior rounded below, somewhat obliquely truncated above; posterior obliquely rounded, faint caudal process above center. Valves moderately convex, thickest in middle. Surface covered with minute pits and widely spaced, normal pore-canals, bears small, low, glassy tubercule at antero-cardinal angle.

Interior of valves moderately deep, marginal area widest anteriorly and in posteroventral region. Line of concrescence at inner margin along midventral border, about halfway in, anteriorly and posteriorly. Anterior and posterior radial pore-canals few, evenly spaced, straight. Margin of right valve with small furrow for reception of sharp edge of left valve.

Muscle scar pattern consists of four elongate scars in ventral row with one elongate anterior scar.

Hinge of right valve consists of anterior, double socket, in front of the cardinal angle, open to interior; serrate furrow, double posterior tooth with posterior part strong, elongate, anterior part weak, serrate. Left valve fitted with corresponding sockets, serrate bar, teeth.—[Edwards, 1944].

Dimensions given.—0.47 to 0.51 mm., long; height, 0.27 to 0.32 mm.

Occurrence.—Moore House Beach at bank base and at four feet up bank: Carter's Grove, bank base and at four and six feet up bank at midbeach. Rare.

Remarks.—Malkin (1953, p. 786-787) has confused *L. purisubrhomboidea* and *L. reticularis*: the forms she figured are closer to *L. purisubrhomboidea* than to *L. reticularis* which has a straighter hinge line and conspicuously coarser reticulate ornamentation. Howe (personal communication) said that in his experience the surface reticulation in *Loxoconcha* is constant for a given species which is at variance with Malkins' views as expressed in her description of *L. reticularis*. I have found only two specimens which answer to the requirements for *L. reticularis;* both are from a well at Ft. Eustis, and their Yorktown age must remain in doubt pending further information.

Loxoconcha reticularis Edwards Pl. 7, figs. 5a-b

Loxoconcha reticularis Edwards, 1944, Jour. Pal., vol. 18, No. 6, p. 527, pl. 88, figs. 26-27.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 274, pl. 10, fig. 7, text fig. 10e.

Carapace subovate in side view. Dorsal outline nearly straight, very slightly concave just posterior to middle; ventral outline straight, converging slightly posteriorly; anterior broadly rounded below, obliquely rounded above middle, posterior obliquely rounded below, very slight caudal process above middle. Externally, flattened marginal border widest anteriorly and posteriorly, forms slight keel on dorsal margin. Surface reticulated concentrically about center of valves.

Hinge in right valve consists of elongate anterior socket deepest in anterior half, crenulate groove, double posterior tooth enclosing shallow socket, posterior part more elongate. Left valve with anterior tooth higher in front half, crenulate ridge, double posterior socket divided by low, rounded wall. Radial pore-canals, line of concrescence characteristic of genus. (Edwards 1944.)

Dimensions given.—Length, 0.44 to 0.52 mm.; height, 0.27-0.29 mm.

Occurrence.—Fort Eustis Well from 37 to 160 feet deep.

Remarks.—The figured form referred to *L. reticularis* is distinguished from the preceding species by having a straight hinge line and considerably coarser reticulation. It agrees with Edwards' form and is not *L. purisubrhomboidea.* From her descriptive paragraphs, it seems doubtful that Malkin found the species in her Yorktown material. As I have found it only in a well of doubtful stratigraphic delineations, it may be that this species is not characteristic of the Yorktown, although it is found in the Duplin marl of North Carolina.

Genus **CYTHERURA** Sars, 1866

Cytherura reticulata Edwards Pl. 7, figs. 7a-b

Cytherura reticulata Edwards, 1944, Jour. Pal., vol. 18, p. 526, pl. 88, figs. 13-16.; Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 50-51.
Cytherura forulata Malkin (not Edwards), 1953, Jour. Pal., vol. 27, pl. 80, figs. 23, 24? (not fig. 22).

Carapace small, elongate, ovate in side view. Dorsal outline of right valve slightly arched; anterior evenly rounded, but with marked concavity near dorsal margin where left valve overlaps, depth of concavity varies slightly; ventral outline concave in middle, posterior with caudal processes characteristic of genus. Dorsal outline of left valve slightly arched, merging gradually with posterior; anterior obliquely rounded; ventral outline slightly concave in middle. Carapace slightly inflated in ventral region. Surface covered with reticulate pattern of ridges forming rectangular pits near margin, square pits in middle of valves. Anterior border, caudal process smooth.

Hinge characteristic of genus. Marginal area broadest anteriorly, of moderate width, crossed by few widely spaced, slightly irregular radial porecanals. (Edwards, 1944.)

Dimensions.—Length, 0.38-0.42 mm.; height, 0.20-0.40 mm. Holotype, length, 0.40 mm.; height, 0.22 mm.

Occurrence.—A single specimen from Camp Wallace.

Remarks.—This specimen from the Yorktown formation seems identical to Malkin's figure for *Cytherura forulata* (Malkin, 1953, pl. 80, fig. 23). The distinct elongate and square pitting of the surface serves to separate this form from *C. forulata* and *C. elongata* whose ornamentation consists of longitudinal ridges with weaker cross ribs. The Yorktown specimen has a more pronounced reticulation than the holotype but is otherwise the same.

Subfamily **CYTHERURINAE** G. W. Muller, 1894

Genus **CYTHEROPTERON** Sars, 1866

Cytheropteron talquinensis Puri Pl. 7, figs. 6a-c

Cytheropteron talquinensis Puri, 1954 (1953), Florida Geol. Surv., Bull. 36, p. 243, pl. 5, figs. 5-7.

Carapace medium, wedge-shaped in dorsal view. Dorsal margin arched; ventral margin sinuous. Anterior end broadly rounded; posterior end subtriangular and sharply produced. Surface of the carapace coarsely reticulate. The ventral ala is subcentral in position; slightly moved toward the posterior.

It is very sharp, pointed and well-developed and coarsely reticulate. Viewed from inside, the valves are deep, marginal areas wide. Hinge normal to the genus. (Puri, 1954.)

Dimensions.—Length, 0.625 mm.; height, 0.371 mm.

Occurrence.—Carter's Grove, base of bank, and also at four feet up bank at midbeach.

Remarks.—This form from the Yorktown formation seems to be like Puri's species. It appears so far to be restricted to the Carter's Grove outcrop but persists there through both "zones" of Mansfield; its presence in Zone II is possibly limited to the basal *Chama* bed of that zone which has several other faunal characteristics suggestive of a transitional facies between Zones I and II. *C. talquinensis* appears to be limited to the *Ecphora-Cancellaria* facies of Puri in the Choctawhatchee of Florida, and it may be a valuable stratigraphic or ecologic marker, probably of more ecologic than other significance.

Subfamily **CYTHERIDEINAE** Sars, 1925

Genus **CLITHROCYTHERIDEA** Stephenson, 1936

Clithrocytheridea diagonalis Malkin Pl. 8, figs. 1a-b

Clithrocytheridea diagonalis Malkin, 1953, Jour. Pal., vol. 27, p. 782-783, pl. 79, figs. 18-19, 21-22, 24.

A specimen from the Crisfield, Maryland, well from a depth of 248-287 feet, is here illustrated to show the similarities and differences between *C. diagonalis* and *C. virginiensis*. *Clithrocytheridea diagonalis* may be ancestral to *Clithrocytheridea virginiensis*.

Clithrocytheridea virginiensis Malkin Pl. 8, figs. 2a-g

Haplocytheridea sp. aff. *H. israelskyi* Swain, 1953, U. S. Geol. Sur., Prof. Paper 234-A, p. 20, pl. 1, figs. 15-17.
Clithrocytheridea virginiensis Malkin, 1953, Jour. Pal., vol. 27, p. 783-784, pl. 79, figs. 23, 25-28.

Carapace ovate; shell thick, translucent; dorsal margin arcuate with blunt, rounded cardinal angulation just anterior to midheight; anterior broadly rounded; posterior rounded, oblique, passing into dorsal margin with a very gradual decrease in slope in right valve; change in slope of posterior margin more abrupt in left valve. In right valve, posterior margin meets ventral at a right angle; in left valve posteroventral angle is more rounded. Greatest extension of posterior is above ventral edge; greatest length of carapace about one-third the distance from ventral edge, measured parallel with ventral margin; ventral margin straight. Greatest height through anterior cardinal angle; greatest convexity central or just posterior of center. Convexity of valves rises more gradually from margins than in *C. diagonalis*. Six or more small but prominent marginal spines on anterior margin. Surface densely pitted; many of the pits in central part of valve in pairs; spaces between the pits form an irregular reticulation. Anterior, ventral and posterior edges of valve ornamented by three low, unprominent plications parallel with margins. Vertical median sulcus slightly above center of valves.

From the interior, valves deep; thick flanges around free margins, with central sinuosity in ventral flange. Lip-line in flange of left valve. Marginal area thick, not wide, with radial pore canals not closely spaced, tending to occur in pairs. Line of concrescence coincides with inner margin ventrally; in the posterior it is just outside inner margin, and further removed from inner margin at anterior end. Hinge taxodont. In right valve a prominent anterior denticulate cusp, followed by a short shallow denticulate groove that merges gradually with a less prominent posterior denticulate cusp, which merges in turn with the posterior marginal flange (TGT); in left valve a deep anterior elliptical denticulate socket, a low denticulate ridge that is higher anteriorly, separated from dorsal margin by a thin depressed line, and a shallow posterior elliptical denticulate socket (SbgS). Muscle scar pattern not observed.

Several molt stages can be recognized, but they are difficult to distinguish from young forms of *Anomocytheridea floridana* unless they are from instars advanced enough to have the deep pitting characteristic of *C. virginiensis*. Young forms figured as *Leptocytheridea mariannensis* Stephenson are similar in shape. (Malkin, 1953.)

Dimensions.—Length, 0.80 mm. to 0.89 mm.; height, 0.48 to 0.50 mm.

Occurrence.—Moore House Beach, base of bank and six feet up bank; Carter's Grove, upper and lower beach bank bases; Carter's Grove, midbeach, 4, 6, and 10 feet up bank; Felgaters Creek; Camp Wallace; Ft. Eustis well at 101-135 ft. deep.

Remarks.—My specimens agree with Malkin's descriptions and figures for this species which she described from the Yorktown formation. The form is possibly diagnostic for the Yorktown formation, but the similar *C. diagonalis* should be studied before decision as to the identity of suspect specimens is made.

Genus **PARACYTHERIDEA** Muller, 1894

Paracytheridea vandenboldi Puri Pl. 8, figs. 4a-b

Cytheropteron nodosum Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 129-130 (vol. I), pl. 38, figs. 37-40 (Vol. II).

Paracytheridea nodosa Howe *et al.*, 1935, Florida Geol Sur., Bull. 13, p. 37, pl. 3, fig. 7.; Van den Bold, 1946, Contrib. Study Ostracoda w/spec. reference to Tertiary and Cretaceous of Caribbean, p. 86, pl. 16, fig. 7.; Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 51, pl. 3, figs. 19-22.

Paracytheridea vandenboldi Puri, 1953, Jour. Pal., vol. 27, p. 751.; Malkin, 1953, Jour. Pal., vol. 27, p. 780, pl. 79, fig. 5.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 238-240, pl. 3, fig. 7, text figs. 5a-b; Swain, 1955, Jour. Pal., vol. 29, p. 625, pl. 62, figs. 2a-b.

Of this remarkable species a single right valve only has been observed. It is strongly but very irregularly convex, with a low and broad swelling in the anterior half, another large protuberance in the postcardinal fourth, a third smaller node just within the depressed and somewhat produced posterior extremity, and a fourth, wing-like prominence, that attains a greater altitude than the other nodes, on the posterior end of a well-defined ventral ridge. In addition to these there is a small spine near the posteroventral angle and a small knob just within the anterodorsal angle. The outline is elongate, subtrapezoidal, the ends subequal, with the anterior slightly the wider, obliquely truncate, converging dorsally. The ventral outline is gently convex and slightly overhung by the posterior third of the ventral ridge. The dorsal outline is slightly concave, the concavity being due chiefly to the projection of the postcardinal node. The central part of the surface is depressed, forming a broad though not sharply defined sulcus. A sharply outlined, bevelled border encloses the ends, the posterior border continuing forward to about the middle of the ventral edge where the bevel is reversed and turned inward to form the small concave area that is more or less readily distinguished on the majority of the Ostracoda of this family. The anterior border does not meet the border coming from the opposite end but passes on above it as an impressed line which gradually becomes obsolete a short distance behind the middle of the ventral side. The surface ornament consists of somewhat scattered pits of moderate size. (Ulrich and Bassler, 1904.)

Dimensions of holotype.—Length, 0.68 mm.; height of both ends about 0.30 mm.; greatest thickness of a single valve, 0.25 mm.

Hinge of right valve consists of an anterior elongate, low, crenulate tooth. Hinge of left valve comprises an anterior shallow crenulate socket, a narrow interterminal crenulate bar, and a posterior, shallow crenulate socket. Inner lamellae not well defined; inner margin and line of concrescence coincide throughout. Muscle scar a submedian vertical row of four spots, with possibly some anterior spots that were not observed clearly. Radial canals few and widely spaced. [Swain, 1951.]

Occurrence.—A single valve from four feet up the bank at the Moore House Beach.

Remarks.—This form was originally described by Ulrich and Bassler (1904) from an undetermined locality on the James River, indicating that it is possibly a Yorktown species. So far as I can determine, the species may be diagnostic for the Yorktown and correlate formations; its rarity makes it a rather unsatisfactory guide species, however. My specimen, as figured, agrees with Ulrich and Bassler's original specimen of *Cytheropteron nodosum*, the holotype for this form.

Subfamily **EUCYTHERINAE** Puri, 1954

Genus **EUCYTHERE** Brady, 1866

Eucythere sp. Pl. 8, figs. 3a-b

Dr. H. V. Howe kindly compared the form with *Eucythere triangulata* Puri and noted that Puri's form is thicker posteriorly and that the shape is different. As only a single valve of the Yorktown form was found, it seems best not to name the specimen but to figure it for future reference.

Dimensions of figured specimen.—Length, 0.55 mm.; height, 0.25 mm.

Occurrence.—Single valve from Carter's Grove, base of bank, general collection.

Genus **CUSHMANIDEA** Blake, 1933

Dr. Henry V. Howe kindly furnished the author with the following information concerning the inavailability of the genus *Cytherideis* and its replacement by *Cushmanidea*:

"Sylvester-Bradley and Harding (Jour. Pal. vol. 27, No. 5, pp. 753-755, 1953) designated for *Cytherideis* as the type, *Cytherideis unicornis* which is a young molt of *Cypridea* Bosquet 1852. The first available name is *Cushmanidea* Blake 1933, with *Cytheridea seminuda* Cushman 1905 as genotype."

This unfortunate destruction of *Cytherideis* as a valid genus will be dealt with in full detail by Dr. Howe in his forthcoming publications. I cite (with his kind permission) Howe's data as a basis for my adoption of the genus *Cushmanidea* for forms now in the literature as *Cytherideis*.

Cushmanidea ashermani (Ulrich and Bassler) Pl. 8, figs. 5a-f

Cytherideis ashermani Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 126 (vol. I), pl. 37, figs. 10-16.; Howe *et al.,* 1935, Florida Geol. Sur., Bull. 13, p. 14, pl. 3, figs. 8-10.; Edwards, 1944, Jour. Pal., vol. 18, p. 514, pl. 86, figs. 1-4.; Swain, 1948, Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 195, pl. 13, fig. 1.; Puri, 1952, Jour. Pal., vol. 26, p. 910, pl. 130, figs. 4-8, text figs. 1-2.; Malkin, 1953, Jour. Pal., vol. 27, p. 778, pl. 78, figs. 1-13.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 286-287, pl. 9, figs. 4-8.

Cytherideis longula Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene p. 138 (vol. I), pl. 37, figs. 21-27. (vol. II).; Swain, 1948, Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 195, pl. 13, fig. 2.

Cytherideis semicircularis Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 127 (vol. I), pl. 37, figs. 18-20 (vol. II).

Carapace elongate, subcylindrical, slightly curved with broadest portion just posterior to middle. Ventral outline almost straight in left valve, slightly sinuate in right, dorsal margin arcuate, ends rounded with posterior more acute than anterior, particularly in right valve; surface strongly pitted and slightly reticulate. Left valve slightly larger than right and overlapping it except along posterior half of dorsal margin. Right valve, viewed from interior, moderately deep; marginal area narrow except around anterior end and flanged from point anterior to dorsal margin around anterior, ventral, and posterior margins; the flange being distinctly removed from outer margin along anterior end and around acute basal tip of posterior end. This flange fits into a lipline which parallels the outer margin of the left valve. The hinge of the right valve consists of an elongate narrow groove on the inrolled dorsal margin and extends from a point just anterior to the middle to the posterior cardinal angle and is terminated at both ends by the projection of the flange previously mentioned. The hinge of the left valve consists of an elongate groove or socket open to the anterior and situated below the dorsal margin just anterior to the middle. A similar, but much smaller, socket is situated at the posterior cardinal end. Between these sockets the dorsal margin is flattened and projecting and fits into the groove of the right valve. The line of concrescence coincides with the inner margin except for short distance around the anterior end, where it lies just inside of it. Normal pore canals are inconspicuous; radial pore canals not well enough preserved to establish pattern, but in several specimens appear to be numerous and grouped in bunches about anterior end. (Howe, 1935.)

Dimensions given.—Length, 0.90 mm. to 1.00 mm.; height, 0.41 mm. to 0.46 mm.; thickness, 0.40 mm.

Occurrence.—Moore House Beach, four ft. up the bank; Langley Field house excavation; Carter's Grove, lower beach portion, base of bank; Camp Wallace; Powell's Lake Spillway.

Remarks.—Yorktown specimens are typical for the species which has a rather extended range in the Miocene and cannot be regarded as diagnostic for Yorktown.

Cushmanidea echolsae (Malkin) Pl. 9, figs. 1a-c, 2a-d

Cytherideis echolsae Malkin, 1953, Jour. Pal. vol. 27, p. 778-779, pl. 78, figs. 14-17.

Mature carapace thick-shelled, elongate, compressed; dorsal margin low arcuate; ventral margin slightly incurved in anterior half; anterior broadly rounded; posterior much more sharply rounded, extended. Height similar throughout, about one-third the length. Anterior and posterior bordered by compressed clear area. Surface marked with coarse angular pits; narrow curved pre-median sulcus.

Interior shallow; marginal area broad with prominent sharp raised lip in right valve that fits into sharp groove inside of free margins of left valve. Dentition desmodont, as in *Cytherideis,* but with high toothlike projection on anterior end of posterior dental ridge. (Malkin, 1953.)

Dimensions.—Length, 0.69 to 0.74 mm.; height, 0.29 to 0.31 mm.

Occurrence.—Moore House Beach at base of bank and six ft. up the bank; Camp Wallace; Carter's Grove, midbeach 10 feet up the bank. Rare.

Remarks.—My specimens seem identical with those of Malkin who described this species from the Yorktown formation. So far as is known, the form is restricted to, and diagnostic of, the Yorktown.

Cushmanidea ulrichi (Howe and Johnson) Pl. 9, figs. 3a-d

Cytherideis ulrichi Howe and Johnson, 1935, in Howe *et al.,* Florida Geol. Sur., Bull. 13, p. 16, pl. 3, figs. 11-14.; Puri, 1952, Jour. Pal., vol. 26, p. 911, pl. 130, figs. 11-3, text figs. 5-6.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 287, pl. 9, figs. 11-13.

Cytherideis subaequalis ulrichi Malkin, 1953, Jour. Pal., vol. 27, p. 779, pl. 78, figs. 18, 21.

Carapace elongate, inflated particularly towards the posterior end. The dorsal margin gently arched, the ventral margin nearly straight, slightly concave just in front of the middle. The anterior and posterior ends obliquely rounded, subequal in the right valve, the posterior slightly larger in the left. Surface of the carapace smooth, but marked with fairly numerous white spots where the normal pore canals approach the surface. Viewed from the inside, the valves are moderately deep, flanked by a well defined marginal area, which is broadest around the anterior end, where, for a short distance, the line of concrescence leaves the inner margin and approaches the outer. Radial pore canals moderately numerous and occurring in bunches of two or three around the anterior end, fewer in number along the ventral and posterior margins. The marginal area of right valve bears a low, sharp flange except for a short distance along the hingeline, where the dorsal margin is grooved. This groove starts at the middle and extends about one-third the distance to the posterior extremity. The marginal area of the left valve bears a faint lipline near the outside and the hinge consists of a sharp infolding of the dorsal margin from the center one-third the distance to the posterior extremity. Behind and below this fold is a short, horizontal gash, in front of it and below the dorsal margin is an elongate, shallow socket. (Howe and Johnson, 1935.)

Dimensions given.—Length, 1.03 to 1.04 mm.; height, 0.47 mm.

Occurrence.—Moore House Beach, bank base; Carter's Grove, bank base, lower beach; Camp Wallace; Fort Eustis well at 101 to 135 feet deep.

Remarks.—Most of my specimens seem undistinguishable from a topotype specimen slide of this species furnished by Dr. Howe. Unfortunately only one specimen from the Yorktown is unarticulated at this writing, and while it is close to the other forms, it differs from them somewhat in outline. In all other respects, the single loose valve agrees with *C. ulrichi.* The hinge structure is somewhat exaggerated in the drawing and suggests *Paracyprideis* according to Howe. I would admit that I would find it difficult to separate the genera *Cushmanidea* and *Paracyprideis* as they are described in the literature, but my forms (even the figured loose valve) appear to me to be closer in outline to *Cushmanidea* than to *Paracyprideis.*

Subfamily **BRACHYCYTHERINAE** Puri, 1953

Genus **LEGUMINOCYTHEREIS** Howe, 1936

Leguminocythereis (?) whitei Swain Pl. 9, figs. 4a-b

Leguminocythereis whitei Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 43, pl. 3, figs. 14, 16-18, pl. 4, fig. 1.; Malkin, 1953, Jour. Pal., vol. 27, p. 785-786, pl. 80, figs. 7-12.

Carapace subtrapezoidal in side view; dorsal margin straight; ventral margin almost straight, protruding slightly in posterior half, converging toward dorsal; anterior margin gently rounded; posterior straight with greatest extension at ventral end; end margins converge towards dorsal edge so that greatest length of carapace is close to ventral margin. Cardinal angles both prominent in left valve; posterior cardinal angle rounded in right valve. Free margins with narrow thickened border most prominent anteriorly and posteriorly; ends denticulate in ventral half on some specimens. Greatest height through anterior cardinal angle; greatest convexity in posteroventral region where the convexity of the valve rises abruptly towards the dorsal edge. Small rounded muscle area anterior of center is present in most valves, obscure in some. Entire surface except marginal borders covered with heavy coarse reticulations that vary in size and pattern. In specimens from younger beds the reticulations tend to be obscured by rugose irregular dendritic plications generally vertical in trend.

Form A; Young molt; archidont hinge; thin shell, small reticulations; prominent muscle spot; very narrow marginal area. Few radial pore canals.

Form B; Moderately thick shell; archidont hinge; few radial pore canals; surface reticulate; reticulations obscured by rugose plications in some specimens. (Malkin, 1953.)

Dimensions.—Length, 0.61 to 0.70 mm.; height, 0.29 to 0.34 mm.

Remarks.—This species probably belongs to a genus other than *Leguminocythereis.* As it seems to me that the species may also be in doubt (*i.e.,* it is not *L. whitei* Swain) and as only one valve of the form was found, it is thought best that a revision of the genus and species be left to some one having better material. The description given by Malkin as cited above seems to agree with the specimen found. The specimen found seems to agree with the form figured by Malkin as figure 10, plate 80.

Occurrence.—Base of the bank, Powell's Lake Spillway, in association with *Isognomen* sp.

Genus **PTERYGOCYTHEREIS** Blake, 1933

Pterygocythereis americana (Ulrich and Bassler) Pl. 9, figs. 5a-d, 6a-e

Cythereis cornuta var. *americana* Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 122 (vol. I), pl. 37, figs. 29-33 (vol. II).

Cythereis alaris Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 123-124 (vol. I), pl. 38, figs. 34-36 (vol. II).

Cythereis (*Pterygocythereis*) *cornuta* var. *americana* Howe *et al.,* 1935, Florida Geol. Sur., Bull. 13, p. 26, pl. 2, figs. 19, 21-24, pl. 4, fig. 24.; Swain, 1948, Maryland Dept. Geol. Mines, and Water Res., Bull. 2, p. 206-207, pl. 14 (13), fig. 4.

Pterygocythereis cornuta americana Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 41-42.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 261, pl. 13, figs. 1-5, text figs. 9d-f.

Pterygocythereis americana Malkin, 1953, Jour. Pal., vol. 27, p. 795, pl. 80, figs. 26-29.

Carapace obliquely subquadrate, the dorsal margin straight and equaling a little more than half the entire length, the ventral edge straight in the middle and at the ends, curving more rapidly into the anterior margin, which is most prominent in the lower half, than into the posterior outline. The latter is the most prominent at a point about a third of the height of the left valve beneath the line of the dorsal edge, and from this point the outline turns anteriorly, at first at a right angle, then with a gentle upward curve on to the well defined post-cardinal angle. The anterio-cardinal angle is sometimes indistinct and always blunter than the posterior angle. The right valve differs from the left principally in this, that both of the cardinal angles are indistinct. Both valves bear a fluted crest, always divided about its mid-length, along the cardinal margin; and a ventral ridge that begins about the middle of the anterior margin with a gradual coalescing series of spines and continues to rise posteriorly until it terminates in a prominent sharp spine, projecting obliquely downward and backward, about one-third of the length of the valve from the posterior extremity. The inner slope of this ridge is fluted like the dorsal crest. From the terminal spine the ridge turns upward toward the postcardinal angle, gradually growing obsolete before reaching it. Two-thirds of the distance intervening between the two points are marked by prominences, the first being a rather prominent node, the second much more obscure. The compressed posterior end terminates in a series of strong spines, six on the left valve and five on the right, while a fringe of smaller spines forms the anteroventral edge. Surface of valves smooth and depressed between the marginal ridges, the valves being on the whole very shallow.

Length of a relatively short valve 1.10 mm.; greatest height of same 0.60 mm.; length of a proportionally long valve 1.20 mm., greatest height of same 0.58 mm. . . . (Ulrich and Bassler, 1904.)

The hinge of the right valve is rather delicate and consists of a moderately small, knob-like tooth on the anterior end, behind which is a small, circular depression which continues as a narrow groove below and parallel to the dorsal margin to the anterior cardinal angle, where is located a low, oval, blunt tooth. The hinge of the left valve is slightly more robust and consists of an anterior socket open below, behind which is a small sharp tooth situated immediately below the dorsal margin. The dorsal margin is thin and sharp and fits into the groove of the opposite valve. The posterior cardinal angle is occupied by an elongate socket open in the interior. The marginal areas are moderately broad on the anterior and posterior ends and carry a few widely spaced radial pore canals. These pore canals tend to be grouped in pairs, particularly on the anterior end. (Howe *et al.,* 1935.)

Occurrence.—Carter's Grove, bank base, upper and lower beach; 10 feet up the bank at midbeach; Moore House Beach, bank base; at 101-135 ft. in Fort Eustis well.

Remarks.—Ulrich and Bassler's *Cythereis alaris* is the young molt of *P. americana,* and my specimens are identical to the types of *C. alaris* with which they were compared. *P. americana* and molts have a distinctively glassy test that serves to assist in relating them, and the hinges of the molts are simple but evolvable into the complex hinge of the adult form. Puri's figure of the hinge structure of *P. americana* leaves something to be desired so far as Yorktown specimens are concerned, the figures here made are decidedly more accurate representations of this feature.

Fimbria Neviani, 1928 has been proposed as the proper name for the genus *Pterygocythereis* on the basis of priority, but the name *Fimbria* has been preoccupied several times for animals other than Ostracoda (Howe, p. 78, 1955).

Subfamily **TRACHYLEBERINAE** Sylvester-Bradley, 1948

Genus **ACTINOCYTHEREIS** Puri, 1953

Actinocythereis exanthemata (Ulrich and Bassler) Pl. 10, figs. 1a-c

Cythere exanthemata Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 117 (vol. I), pl. 36, figs. 1-5 (vol. II).

Cythereis exanthemata Swain, 1948, Maryland Dept. Geol., Mines and Water Res., vol. 2, p. 204, pl. 12, figs. 14-15.

Trachyleberis exanthemata Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 37, pl. 6, fig. 5.; Malkin, 1953, Jour. Pal., vol. 27, p. 791, pl. 81, figs. 16, 19-20.

Actinocythereis exanthemata Puri, 1953, Amer. Midland Naturalist, vol. 49, p. 179-181, pl. 2, figs. 4-8, text figs. 3-f.; Puri, 1954 (1953), Florida Geol. Sur. Bull., vol. 36, p. 252-253, pl. 13, figs. 6-13.

Actinocythereis aff. *exanthemata* Swain?, 1955, Jour. Pal., vol. 29, p. 634, pl. 63, figs. 5a-b, text figs. 37c, 38, 7a-c.

Carapace oblong subquadrate or elongate subovate, obliquely rounded at the ends, the greater curvature and prominence in both cases being in the ventral half. Entire outline, excepting the straight or slightly concave ventral edge, fringed with flattened spines, those along the dorsal edge being of larger size than those on the ends. Posterior end compressed and carrying a double series of spines, the outer row sometimes occupying a low marginal ridge. Anterior end with a thick border or marginal ridge within the spiny fringe, but this ridge also breaks up into node-like spines in its lower third. Surface of valves between these two end ridges covered with fifteen to eighteen large irregular blunt spines or excrescences. These spines at first sight may seem to be arranged wholly without regard to any system, but on closer inspection they arrange themselves into three longitudinal rows, a rather irregular one projecting over the dorsal line, a second regular series beginning with the nodes on the lower end of the anterior marginal ridge and continuing in an increasing curve across the ventral and posterior slopes, and a third and much less regular row lying between the other two. Several of the nodes of the middle series are grouped on the summit of a broad anterior swelling of the valves. Hingement strong, typical for the genus. The interior marginal plate is usually wide. (Ulrich and Bassler, 1904.)

Length, 0.90 mm.; height, 0.50 mm.

Marginal area broad, with a lipline and many paired marginal pore canals which generally are straight, sometimes are wavy, but are never thickened. Muscle scar pattern consists of four oval spots in a vertical row, a fifth is in front of the middle and a sixth is below it. Hinge line of the right valve consists of an anterior tooth, a postjacent socket and a posterior tooth connected with a shallow median groove.—(Puri, 1954, p. 252.)

Occurrences.—Confined to Carter's Grove, bank base upper and lower part of beach and at middle part of beach, four, six, and ten feet up bank. Rare.

Remarks.—Yorktown specimens are typical.

Actinocythereis exanthemata gomillionensis (Howe and Ellis)
Pl. 10, figs. 2a-d

Cythereis exanthemata var. *gomillionensis* Howe and Ellis, 1935, Howe *et al.*, Florida Geol. Sur., Bull., vol. 13, p. 19, pl. 1, figs. 6-12, pl. 4, fig. 3; Edwards, 1944, Jour. Pal., vol. 18, p. 521, pl. 87, figs. 31-32.

Trachyleberis exanthemata gomillionensis Malkin, 1953, Jour. Pal., vol. 27, p. 792, pl. 81, figs. 15, 17-18.

Actinocythereis exanthemata var. *gomillionensis* Puri, 1953, Amer. Midland Naturalist, vol. 49, p. 181, pl. 2, figs. 1-2.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 253, pl. 13, figs. 16-17.

Variety differing from the preceding (*C. exanthemata* var. *marylandica* Howe and Hough) in its much smaller size, more elongate form, more delicate ornamentation and in the greater number of nodes which decorate the central portion of the carapace. In particular there are usually three additional nodes in front of the central row of spines placed approximately equidistant between the muscular tubercle and the anterior rim. In addition this variety possesses a supplementary row of very fine, globular nodes situated above the dorsal row of spines along the hinge-line of the right valve. In most specimens this line of nodes extends the entire distance from the anterior cardinal angle to the posterior cardinal angle, but in some specimens is found only on the anterior half of the hinge-line. This supplementary row of nodes easily separates this variety from either the preceding variety or from the typical species. (Howe and Ellis, 1935.)

Dimensions.—Length, 0.73-0.79 mm.; height, 0.39-0.43 mm.; thickness, 0.43 mm.

Another feature which seems to separate this form from the typical species and the subspecies *marylandica* is the restriction of radial pore canals to the posterior and anterior marginal areas, as figured by Howe and Ellis and on my figured specimens.

Occurrence.—Camp Wallace; Carter's Grove at base of bank along entire outcrop and at 10 feet up the bank at upper part of beach; also at Moore House Beach, bank base and six feet up the bank.

Remarks.—Malkin (1953, p. 792) called this form an "allochronic subspecies" of *A. exanthemata* and *A. exanthemata marylandica.* As far as I can ascertain, the form *A. gomillionensis* may be restricted to the Yorktown formation and its correlate formations.

Genus **ECHINOCYTHEREIS** Puri, 1953

Echinocythereis clarkana (Ulrich and Bassler) Pl. 10, figs. 3a-c

Cythere clarkana Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 98, (vol. I), pl. 35, figs. 1-10 (vol. II).
Cythere clarkana var. *miniscula* Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene, p. 99 (vol. I), pl. 35, figs. 11-14 (vol. II).
Leguminocythereis clarkana Swain, 1948, Maryland Dept. Geol. Mines and Water Res., Bull. 2, p. 207, pl. 14, fig. 6.; Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 43, pl. 6, fig. 18.
Trachyleberis clarkana Malkin, 1953, Jour. Pal., vol. 27, p. 792, pl. 82, figs. 1-3.

Carapace rather irregular in outline but usually elongate-ovate, about 1.30 mm. in length, 0.65 mm. high and 0.6 mm. thick. Valve well-rounded, the greatest convexity towards the posterior end, unequal, the left overlapping the right at the cardinal angles and in turn overlapped by the right along the ventral edge. Position of anterior hinge teeth marked by an oblique dorsal swelling. Hinge straight, the length being about three fifths that of the entire carapace. Left valve obliquely rounded posteriorly, most prominent in the lower half; ventral edge straight or slightly arcuate; the posterior edge rather narrowly rounded, the curve generally straightened in the upper half, and the junction with the extremity of the hinge line sometimes obtusely angular. In the right valve the ends are more equal in breadth and curvature, although the ventral half of the anterior is also more strongly curved, and the ventral outline is faintly sinuate instead of arcuate. Surface of both valves coarsely reticulate, the meshes arranged somewhat concentrically about a subcentral point. The ridges forming the raised part of the network bear, especially at their junction angles, spines, the size and number of which vary with age. In the old condition, the surface is quite rough with these spines, the ridges thicker and the reticulation less obviously concentric. The lower two-thirds of the anterior and posterior margins of the left valve bear a series of small spines but on the right valves such spines have been observed only on the anterior edge and they are often wanting even there. Edge view lanceolate with the ends a little blunt or truncate. Hingement consists of a rather large anterior lateral tooth connected by a bar with a somewhat smaller posterior tooth and corresponding sockets in each valve. (Ulrich and Bassler, 1904.)

Hinge of left valve consists of the following elements: a small, deep, rounded, anterior socket, supported ventrally by a pronounced, ridgelike, subvertical shell-thickening; a larger, deep, rounded, posterior socket; and an intervening heavy bar, formed of the thickened valve edge, bluntly club-shaped at its posterior end, expanded and with slightly depressed surface at its posterior end; dorsally the ridge is defined by a weak furrow. Hinge of right valve not observed here, but according to Ulrich and Bassler, it consists of terminal, rounded teeth connected by a bar; the relationship of the connecting bars is not clear, but it appears that in the right valve, the thin valve-edge slightly overlaps the strong bar on the left valve.

Muscle scar slightly anterior to midlength; it consists of a curved, subvertical row of four spots, together with two more anterior spots that lie adjacent to one another; between the two groups of spots is a deep, rounded pit. Inner surface bears numerous, small, rather widely spaced pits that represent the positions of the pore canals. Marginal pore canals numerous; inner margin and line of concrescence not quite coinciding, either terminally or ventrally. Ventral margin of left valve impressed medially, where it seems to be overlapped slightly by the edge of the right valve. (Swain, 1948.)

Occurrence.—Crisfield well (Maryland) at 287 to 388 feet; Fort Eustis well at 101-160 feet; W. bank of Fishing Creek 11 miles north of Tarboro, N. C. Ulrich and Bassler reported this form from Yorktown, Virginia, but neither Miss Malkin nor I have found any specimens either at Yorktown or in the Yorktown formation. Swain (1951) found it in the upper Miocene of the Bogue, North Carolina well, but the Bogue fauna available to the author is not correlative with the Yorktown formation faunas as far as can be determined at present.

Remarks.—So far as I am able to determine, this species is diagnostic of the pre-Yorktown; it has not been found in Yorktown formation outcrops.

Genus **MURRAYINA** Puri, 1954

Murrayina howei Puri Pl. 10, figs 4a-e

Cythere producta Ulrich and Bassler (not Brady), 1904, Maryland Geol. Sur. Miocene, p. 115 (vol. I), pl. 36, fig. 17, pl. 38, figs. 28-30 (vol. II).

Cythereis products Howe, 1935, in Howe *et al.*, Florida Geol. Sur. Bull. 13, p. 22, pl. 1, figs. 31-32, 35, 37, pl. 4, figs. 11-12.

Trachyleberis martini Malkin, 1953, Jour. Pal., vol. 27, p. 793, pl. 82, figs. 6-9 ?, 11-13 ?.

Murrayina howei Puri, 1954 (1953), Florida Geol. Sur. Bull., 36, p. 255-256, pl. 12, figs. 9-10, text figs. 8g-h.

Carapace in side view elongate ovate, dorsal and ventral margins slightly sinuous and nearly parallel, the anterior end broadly and obliquely rounded and forming a distinct and prominent angulation with the dorsal margin, produced ventrally, faintly rimmed and decorated with eight to ten small marginal teeth below the middle. The posterior end rounded, but tending to a slight angularity just above the middle. It, too, tends to be faintly denticulate. The remainder of the surface is reticulate with a tendency for the reticulations to be elongated longitudinally. There is a low swelling marking the position of the muscle attachment just anterior to the middle and the eyespots are small, circular and very clearly defined. Greatest height at the anterior cardinal angle; greatest thickness near the posterior end, but it is only slightly more than the thickness near the anterior end. Viewed from the inside, the valves are moderately shallow, particularly at the anterior ends and fringed with a fairly wide marginal area. The line of concrescence lies between the inner and outer margins, around the anterior end and around the central portion of the posterior end. The marginal area of the right valve bears a broad, shallow lip-line near the outer margin, into which the acute outer margin of the left valve fits. The ventral margin of both valves are incurved and flanged just anterior to the center, the flange of the left valve being bifid. The hinge of the right valve consists of a high, sharp anterior tooth, whose base curves posteriorly downward below a deep anterior socket which is situated, immediately above and behind, a small circular, ocular pit. The inner edge of the dorsal margin appears to be faintly grooved and the posterior cardinal angle is occupied by a large, oval, mushroom-shaped tooth. The hinge of the left valve consists of a deep, circular, anterior socket, situated above and behind a small, circular, ocular pit and separated from it by a low, thick septum. The dorsal margin projects in a tooth-like manner immediately in front and behind the socket, otherwise it is straight, narrow and sharp to the posterior angle, where is situated an ovate pit, partially open to the interior. The radial pore canals are numerous; normal pore canals are few and widely spaced and mostly obscured by the reticulate ornamentation. (Howe *et al.,* 1935.)

Dimensions.—Length, 0.90 mm.; height, 0.42 mm.; thickness, 0.37 mm.

Occurrence.—Powell's Lake Spillway; Fort Eustis well at 101-135 feet; Crisfield (Maryland) well at 248 to 287 feet deep. Rare. Not encountered in outcrop material from the Yorktown formation, though the Fort Eustis interval is believed to be in the Yorktown formation.

Remarks.—Miss Malkin believed this form to be a phenotypic variant of *M. martini,* but I find the hinge structure and the ornamentation somewhat different from *M. martini.* These features plus a difference of outline of the test seem to separate the forms in question.

Murrayina martini (Ulrich and Bassler)

Pl. 11, figs. 1a-c, 2a-b, 3a-d

Cythere martini Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene, p. 112-113 (vol. I), pl. 36, figs. 11-15 (vol. II).

Cythere micula Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene, p. 116 (vol. I), pl. 36, figs. 18-20 (vol. II).

Cythereis martini Swain, 1948, Maryland Dept. Geol., Mines, and Water Res., Bull. 2, p. 196, pl. 12, figs. 16-17.

Trachyleberis ? martini Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 29, pl. 3, figs. 8,15.

Trachyleberis martini Malkin, 1953, (Part), Jour. Pal., vol. 27, p. 793, pl. 82, fig. 10?, (not other figures).

Murrayina martini Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 256, pl. 12, figs. 11-13, text figures 8e-f.

Carapace small, suboblong, widest anteriorly though the difference between the heights of the two ends is variable and sometimes does not exceed the difference between five and six. Right valve with a long, straight dorsal edge, terminating anteriorly and posteriorly in rather distinct angles; anterior edge with a thick border, obliquely subtruncate, and usually with a fringe of short spines in the middle and lower thirds; posterior outline sometimes uniformly curved backward from the anterodorsal angle and then forward again into the nearly straight ventral margin, the curve into the latter being gradual.

More commonly, however, especially when the posterior fringe of five or six spines is well developed, there is a small excision in the upper third of the outline. Often a small prominence is noticeable about the middle of the ventral edge. Left valve generally a little higher than the right, which it overlaps ventrally, and enclosed, except along the dorsal edge, by a thick rim, heaviest anteriorly and barely distinguishable in the anteroventral region. Usually there are no marginal spines at either end of this valve. Both valves exhibit a broad swelling, occupying the greater part of the anterior half, but it is nearly always more conspicuous on the left valves. The surface of the right valves, on the contrary, seems to be more protuberant near the posterior margin than the left. Occasionally the right valve bears also a small central protuberance. Surface of both valves reticulate or simply pitted, the pattern, as shown by the illustrations, being somewhat variable. (Ulrich and Bassler, 1904.)

Dimensions.—Length, 0.75 mm. to 0.80 mm.; height, 0.39 mm. to 0.42 mm.

Hinge of right valve consists of an anterior, strongly elevated, pointed tooth, a postjacent rounded socket, a posterior, strongly elevated, pointed tooth, in front of which is a small, subtriangular, shallow socket, and between these terminal dental areas, the valve edge bears a very faint groove . . . . Marginal pore canals arranged in pairs, about 30 on each end. Inner lamellae fairly broad, the inner margin and line of concrescence coinciding. Muscle scar lies anterior to midlength and consists of a compact group of four spots; additional spots may be present dorsal and anterior to the main group, but could not be observed clearly." (Swain 1948).

Hinge of left valve the antithesis of right, but interterminal bar is only faintly crenulate in a few places. (Swain, 1951.)

Occurrence.—Camp Wallace; Carter's Grove throughout section; Moore House Beach at base of bank and four feet up bank; Fort Eustis well at 135-160 feet deep.

Murrayina barclayi McLean, n. sp. Pl. 11, figs. 4a-f

Carapace elongate, subtrapezoidal, dorsal and ventral margins slope slightly towards posterior end; dorsal margin straight, ventral margin with a distinct incurving midportion. Anterior end broadly rounded, with numerous small spines extending from just below the anterior angle to and around the ventral portion. Posterior end slightly rounded to straight, forming distinct angles with the dorsal and ventral margins and with several well-developed spines in lower half. Ornamentation strikingly and strongly reticulate; reticulae arranged in concentric curves anteriorly, arrangement over rest of test is determined by several well-developed longitudinal ridges which occupy the midpart of the test and fan out downward posteriorly.

Greatest height at the anterior cardinal angle which projects a bit above the dorsal margin. Internally the valves are moderately deep, with broad marginal areas which show numerous fine radial pore canals. The marginal area of the right valve has a relatively broad, shallow lip line to receive the left valve. The hingement of both valves are strongly developed and typical of the genus. Normal pore canals, line of concrescence, and muscle scars not observed in holotype or paratype specimens. The form figured as a molt seems close to this species in shell texture and is primitive in character as befits a young molt which modifies into the more complex, fully detailed, adult form. The hinge is simple and straight but begins to show signs of the more complex adult hinge structure.

Dimensions.—Length of holotype, 0.80 mm.; height, 0.40 mm.

Occurrence.—Moore House Beach, base of bank.

Remarks.—This species is quite close to *M. howei,* from which it differs in the distinctive ornamentation, slenderer test, and somewhat stronger hinge details. It may be a descendant or variant of *M. howei.* Named in honor of Mr. George Barclay of Newport News, Virginia, who kindly helped the author in locating collection spots, and who has been unfailingly encouraging and helpful in other ways. *Murrayina barclayi* could possibly be referred to Malkin's *Trachyleberis radiata,* but her description leaves much to be desired and her figures show a coarser ornamentation that is not developed in the fashion of *M. barclayi.*

Genus **ORIONINA** Puri, 1954

Orionina vaughani (Ulrich and Bassler) Pl. 11, figs. 6a-b

Cythere vaughani Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 109-110 (vol. I), pl. 38, figs. 25-27 (vol. II).

Cythereis vaughani Howe *et al.,* 1935, Florida Geol. Sur., Bull. 13, p. 24-25, pl. 3, figs. 24-26, pl. 4, fig. 12.; Coryell and Fields, 1937, Amer. Mus. Nat. Hist. Novitates, No. 956, p. 9, fig. 10a.; Edwards, 1944, Jour. Pal., vol. 18, p. 522, pl. 87, figs. 27-28.; Van den Bold, 1950, *ibid.,* vol. 25, p. 83.

Trachyleberis vaughani Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 37, pl. 6, figs. 6-7.; Malkin, 1953, Jour. Pal., vol. 27, p. 794, pl. 82, fig. 14.

Orionina vaughani Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 254, pl. 12, figs. 15-16, text figs. 8a-c.

Carapace elongate with an obliquely rounded anterior end and a posterior end that is rounded below the middle and concave above. The dorsal margin is nearly straight, the ventral subparallel to it and slightly sinuous. The anterior, ventral and lower half of the posterior margins are finely and evenly denticulate, particularly in the right valve. Viewed from the outside, the anterior end carries a thin marginal rim. Surface with three or four longitudinal ridges and an irregular number of transverse raised bars, forming an angularly reticulate pattern which is somewhat variable. In addition to the pattern of ridges, the valves bear a small, round, almost glassy knob just in front of the center and a somewhat similar glassy tubercle at the 'eyespot' just below the anterior cardinal angle. Viewed from the interior, the valves are moderately deep and are fringed with a fairly broad marginal area, which, in the right valve, carries a deeply grooved lip-line near the outer margin to receive the rather acute marginal edge of the opposite valve. Radial pore canals are numerous and closely spaced around the anterior end, becoming fewer and wider spaced along the ventral and posterior margins. The hinge of the right valve consists of a small, knob-like anterior tooth, in front and below which lies a small ocular pit and behind which is a large, shallow depression open to the interior. This pit is situated below a long, straight, narrow, oblique hinge bar, which terminates at the posterior cardinal angle above a small, round, knob-like tooth which is situated on the posterior margin. The hinge of the left valve consists of a small anterior socket, situated above and behind a deep ocular pit and separated from it by a low rim, and with two tooth-like projections, one just in front, formed by an overlap of the dorsal margin, the other immediately behind and below the dorsal margin. The dorsal margin is nearly straight and oblique and faintly grooved. The posterior cardinal angle is occupied by a large, shallow socket, which is elongated parallel to the posterior slope. (Howe *et al.*, 1935.)

Occurrence.—Sporadically throughout the Carter's Grove outcrop; at base of the bank at the Moore House Beach; Langley Field house excavation.

Remarks.—This form is reported as low as the middle Miocene of North Carolina and the *Arca* Zone of Florida Miocene. The form in the York-James Peninsula seems to be restricted to the Yorktown formation, and it is also reported to be living off the coast of Haiti.

Genus **PURIANA** Coryell and Fields, 1954

Puriana rugipunctata (Ulrich and Bassler) Pl. 11, figs. 5a-d

Cythere rugipunctata Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 118 (vol. I), pl. 38, figs. 16-17, (vol. II).

Cythereis rugipunctata Howe *et al.*, 1935, Florida Geol. Sur., Bull. 13, p. 23, pl. 1, figs. 18, 20-22; pl. 4, figs. 22-23.

Favella rugipunctata Edwards, 1944, Jour. Pal., vol. 18, p. 524, pl. 88, figs. 5-6.; Malkin 1953, Jour. Pal., vol. 27, p. 797, pl. 82, fig. 24.; Van den Bold, 1950, Jour. Pal., vol. 24, p. 86.; Van den Bold, 1946, p. 100, pl. 10, fig. 3.

Trachyleberis ? rugipunctata Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 38, pl. 6, fig. 8.

Puriana rugipunctata Coryell and Fields, (in Puri, 1953), Jour. Pal., vol. 27, p. 751.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 257-8, pl. 12, figs. 18-19, text fig. 8 k.

Carapace in side view elongate ovate; highest at the anterior cardinal angle; thickest at the muscular protuberence. Anterior end broadly and obliquely rounded with a distinct rim and with four or five small marginal spines in the ventral half; posterior end concave in the dorsal half, convex and ornamented with three or four prominent spines in the ventral half. Dorsal margin nearly straight, ventral margin sinuous, with two margins tending to converge posteriorly. Ornamentation of the central portion of the carapace consisting of a prominent node just anterior to the center, behind and below which is a curved sulcus. The surface of the posterior half of the carapace is a complex of oblique plications which tend to produce a divaricate effect along the median line of the valves. Anterior to the central node, the plications are irregularly distributed. There is a small, ocular spot just below the anterior cardinal angle. Viewed from the inside, the valves are moderately deep and are bordered with a wide marginal zone, widest along the posterior half of the ventral margin. The marginal area of the right valve possesses a well-marked 'lip line' just inside the outer margin, into which the acute outer margin of the left valve articulates. The radial pore canals are moderately few in number, being most abundant around the anterior end. The hingement of the right valve is elongate and consists of a small, high anterior tooth, behind which is a deep socket, tending to be open to the interior. From this socket a narrow, straight groove parallels the dorsal margin to the oblique, blunt, recurved posterior tooth. There is also a second groove below the first, which starts at the anterior socket and continues back about one-fifth the distance to the posterior cardinal angle. The hinge of the left valve consists of a small anterior socket behind which is a moderately high tooth, followed by a straight bar parallel to and separated from the dorsal margin by a faint incised line. This bar terminates at its posterior end in a small swelling and is in turn followed by a wide, oblique socket, which is open to the interior of the valve. (Howe *et al.,* 1935.)

Dimensions.—(Howe *et al.*). Length, 0.65 mm.; thickness, 0.36 mm.; height, 0.38 mm. (Ulrich and Bassler); Length, 0.71 mm.; thickness, 0.20 mm. (single valve); height, 0.38 mm.

Occurrence.—Rare; Langley Field house excavation; Carter's Grove six feet up the bank at midbeach section; Powell's Lake Spillway, Camp Wallace.

Remarks.—This form seems to be restricted to the Miocene but appears in all parts of the Miocene according to recorded occurrences.

Genus **ACUTICYTHEREIS** Edwards, 1944

Acuticythereis laevissima Edwards Pl. 12, figs. 4a-g

Acuticythereis laevissima Edwards, 1944, Jour. Pal., vol. 18, No. 6, p. 519-520, pl. 87, figs. 4-11.
Camplocythere laevissima Malkin, 1953, Jour. Pal., vol. 27, No. 6, p. 785, pl. 80, figs. 4-6.

Carapace ovate to pyriform in side view, posterior pointed, dorsal outline straight, anterior obliquely rounded, ventral outline concave just anterior to middle. Posterior of right valve pointed, left more rounded. Surface smooth, but marked by irregularly spaced, normal pore-canals.

Hinge, marginal area and radial pore-canals characteristic of genus but in immature molts, radial pore-canals not grouped nor do they indent line of concrescence. (Edwards, 1944.)

Dimensions.—Length, 0.70 to 0.77 mm.; height, 0.31 to 0.38 mm.

Occurrence.—Felgater's Creek; Moore House Beach at base of bank; Carter's Grove, lower part of beach at bank base and also at midbeach section six feet up the bank, Langley Field house excavation.

Remarks.—The figures here made of Yorktown specimens indicate a somewhat stronger hinge development than is actually the case, but the essential details are correct. I see no reason to transfer this form to *Camplocythere* as Malkin has done. The pores of the holotype are more prominent than is the case with Yorktown specimens. Edwards' paratypes had the same type of pores as Yorktown specimens.

Subfamily CYTHERETTINAE Triebel, 1952

Genus CYTHERETTA Muller, 1894

Cytheretta burnsi (Ulrich and Bassler) Pl. 12, figs. 1a-d

Cythere burnsi Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 103 (vol. I), pl. 36, figs. 34-39 (vol. II).
Cythere nitidula Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 107 (vol. I), pl. 36, figs. 21-28 (vol. II).
Cythere nitidula var. *calvertensis* Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 108 (vol. I), pl. 36, figs. 24-25 (vol. II).
Cythere paucipunctata Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 105, (vol. I), pl. 38, figs. 7-9 (vol. II).
Cytheretta burnsi Howe *et al.,* 1935, Florida Geol. Sur., Bull. 13, p. 33, pl. 2, figs. 12-14, 17, pl. 4, figs. 14, 21; Puri, 1952, Jour. Pal., vol. 26, p. 205-206, pl. 39, figs. 5-6.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 282, pl. 7, figs. 1, 2.; Malkin, 1953, Jour. Pal., vol. 27, p. 789-790, pl. 81, figs. 7-8, 10-11.

> Carapace elongate ovate, highest and thickest near the posterior end, the dorsal margin straight, the ventral margin sinuous, the anterior and posterior ends broadly rounded. The central part of the valves is ornamented by a reticulate pattern of pits and ridges; many of the pits occurring in pairs and tending to be hexagonal in outline and the sculpture being longitudinal in its arrangement. The left valve is larger than the right and overlaps it, particularly at the cardinal angles. Viewed from the inside, the valves are moderately deep with a broad marginal area, the interior margin of the anterior end possessing the characteristic 'S' shape of the genus. The radial pore canals are very elongate and fairly numerous. On the anterior end they radiate from a point just in front of the muscle scars. The outer edge of the right valve is thickened and sharp and slightly keeled toward the center of the ventral margin. In the left valve there is a faint lipline which lies just within the outer margin. The hinge of the right valve consists of a strong anterior tooth, shaped like a pointed triangular pyramid. Behind it lies a deep socket open to the interior. From the posterior side of this socket, a shallow groove extends half-way back along the hinge line. The edge of the dorsal margin is straight and carries a faint groove. The posterior tooth is strong rounded, oblique and recurved in the direction of the posterior extremity. The hinge of the left valve consists of large terminal sockets which are at least partially open to the interior. The anterior socket is flanked in front by a strong, tooth-like projection of the dorsal margin; behind by a heavy, blunt, inwardly deflected tooth. The posterior socket is flanked behind and partially covered by a long pointed fold of the margin. Between the sockets there is a narrow, minutely crenulate, straight bar, separated from the dorsal margin by a faintly incised line. (Howe *et al.,* 1935.)

Dimensions given by Howe *et al.* are: left valve, length, 1.28 mm.; height, 0.66 mm.; right valve, length, 1.24 mm.; height, 0.63 mm.

Occurrence.—Langley Field house excavation; throughout the section at Carter's Grove but rare in all cases.

Remarks.—Doris Malkin (1953, p. 789-790) gave several molt stages of this species a detailed description. Our specimens were rare and did not include these different stages, although I am inclined to agree with Malkin's synonymy and descriptions of this form.

Cytheretta ulrichi Puri Pl. 12, figs. 3a-d

Cythere plebeia Ulrich and Bassler (Not Reuss), 1904, Maryland Geol. Sur. Miocene, p. 102-103 (vol. I), pl. 35, figs. 20-29 (vol. II).
Cythere plebeia var. *capax* Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 103 (vol. I), pl. 35, figs. 30-33 (vol. II).
Cythere porcella Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, p. 106-107 (vol. I), pl. 36, figs. 26-33 (vol. II).
Cytheretta plebeia Swain, 1948, Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 212, pl. 14, figs. 3-4.; Malkin, 1953, Jour. Pal., vol 27, p. 790, pl. 81, figs. 1-6, 9.
Cytheretta ulrichi Puri, 1952. Jour. Pal., vol. 26, p. 204-205, pl. 39, fig. 3, text figs. 5-7.
Cytheretta porcella Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 45, pl. 4, fig. 7.

Carapace elongate, outline approximately a parallelogram. Valves moderately and evenly convex, greatest height slightly posterior to center, Dorsal margin straight, slightly convex; ventral margin straight, slightly concave just anterior to middle, but generally parallel to dorsum. Anterior end blunt, obliquely rounded, more so in upper half. Posterior end narrow, obliquely rounded in ventral half, oblique above. Surface smooth with shallow, rounded, scattered pits having no regular pattern except that they tend to occur in pairs. As viewed from inside, valves moderately deep, thick. Marginal areas very broad. Line of concrescence coincides with inner margin, forms the characteristic S-line of genus. Radial pore canals fairly numerous, straight, slender, with tendency to occur in pairs, more numerous along anterior than posterior or ventral margins, where they are scanty. Hinge in left valve consists of anterior and posterior sockets flanked by tooth-like projections of dorsal margin connected by a bar-like ridge. Hinge in right valve consists of an anterior conical tooth, almost vertical in front and sloping steeply behind, a postjacent socket and a somewhat smaller posterior conical tooth connected by a deep, narrow groove. (Puri, 1952.)

Dimensions.—(Puri.) Length, 0.952 mm. to 0.980 mm.; height, 0.490 mm. to 0.540 mm.

Occurrence.—Moore House Beach, base of bank; Langley Field house excavation; Carter's Grove, in upper part of beach at base and 10 feet up the bank; Powell's Lake Spillway, top and bottom beds; Fort Eustis well at 101-135 feet deep; Crisfield (Maryland) well at 248-287 feet.

Subfamily **HEMICYTHERINAE** Puri, 1953

Genus **HEMICYTHERE** Sars, 1925

Hemicythere schmidtae Malkin Pl. 12, figs. 2a-d

Trachyleberis ? cf. T. angulata, Swain, 1951 (not Sars) U. S. Geol. Sur., Prof. Paper 234-A, 29-30, pl. 3, figs. 9-12.
Trachyleberis ? reesidei Swain, 1951, U. S. Geol. Sur. Prof. Paper 234-A, p. 30, pl. 3, fig. 13.
Hemicythere schmidtae Malkin, 1953, Jour. Pal., vol. 27, p. 796-797, pl. 82, figs. 16-18

Carapace elongate subovate; dorsal margin slightly arched; ventral margin slightly sinuous, tending to converge with dorsal; anterior broadly rounded and curving into ventral margin, may be finely denticulate; posterior almost straight, oblique, with blunt short caudal extension, which may be denticulate, near ventral edge. Cardinal area extends above rest of dorsal margin. Greatest height through anterior cardinal angle; convexity similar throughout. Entire margin with a thickened, rounded clear border, broadest anterior and posterior; the thickened border rises from the margin to form a rounded rim on anterior and posterior ends. Surface, except rims and borders, covered with coarse, irregular, angular reticulations, arranged in a roughly radial pattern, and with normal pore canals in the large inter-reticular spaces. Eye spot in anterior cardinal area; large rounded muscle area anterior of center. Clear ventral ridge extends between anterior and posterior rims parallel with ventral margin at the edge of the convexity of valve, and terminates posteriorly in a low acumination. A similar ridge branches from dorsal border ridge, about one-third of the distance from posteriorcaudal acumination, ending in a blunt spine before reaching the rim.

Form A: Young molt; similar in all respects except hinge and marginal area, to adult form, but more fragile, thinner, more delicately ornamented. Hinge simple, weak, archidont, consisting of thin, rounded elliptical to blade-like very delicately cuspate terminal teeth and faintly denticulate groove in right valve; corresponding shallow sockets and faintly serrate ridge in left valve. Marginal area narrow, radial pore canals few, widely spaced.

Form B: Adult carapace; interior of valves moderately deep; marginal area wide; line of concrescence almost coincident with inner margin; radial pore canals numerous. A fine, thread-like lip near outer edge of marginal area of right valve fits into a fine lip-line near outer edge of left valve. Hinge strong; in the right valve a large knob-like elliptical two-cusped tooth in front of a small socket occupies anterior cardinal angle; long subdorsal groove shallow posterior socket and elliptical tooth fit into the complimentary structures of the left valve. In left valve a large deep elliptical anterior socket with a narrow opening into interior; behind the socket a low elliptical tooth continuous with a thin finely crenulate ridge that ends in a low rounded prominence in front of an elliptical posterior socket in posterior cardinal angle. Length 0.63 to 0.69 mm.; height 0.35 to 0.45 mm. (Malkin, 1953.)

Occurrence.—Powell's Lake Spillway; Moore House Beach at base, at four and at six feet up bank; throughout the section at Carter's Grove.

Remarks.—This form may be the *Hemicythere howei* Puri (1953a, p. 176, pl. 1, figs. 709), but as Puri's form is figured, the caudal extension is much more pronounced than Malkin's species and my specimens indicate.

It is important to note, however, that both authors differentiated their species from *H. conradi* (Howe and McGuirt) in almost the same manner, so that there is reason to suspect that the two are synonyms. If this be so, Puri's name for the species has priority.

On the other hand, the inner details of Swain's *Trachyleberis* ? cf. *T. ? angulata* from the North Carolina Miocene are close to

H. schmidtae from the Yorktown formation. Also, the *Trachyleberis ? reesidei* from Swain's North Carolina material seems to be the same as *H. schmidtae*. In his original description of *T. reesidei*, Swain stated that the species was based on a specimen found in the Cretaceous level of a Maryland well. The presence of this same species in the Miocene is explained by Swain as being possibly due to redeposition of Cretaceous material into Miocene beds. It seems that the presence of the single specimen (holotype) of *T. reesidei* is open to suspicion as being a contaminating element from upper beds of the Maryland well. One would expect to find more than one specimen in a given bed where it died.

This species seems to be restricted to the Yorktown and its correlate formations, although the questions of species noted above may change this distribution somewhat if *H. schmidtae* is found to be equivalent to them.

Genus **AURILIA Porkorny,** 1955

Aurilia conradi (Howe and McGuirt) Pl. 11, figs. 7a-b

Hemicythere conradi Howe and McGuirt, 1935, Florida Geol. Sur., Bull. 13, p. 27-28, pl. 3, figs. 31-34, pl. 4, fig. 17.; Edwards, 1944, Jour. Pal., vol. 18, p. 518, pl. 86, figs. 17-18.; Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 42, pl. 6, figs. 9-12.; Puri, 1953, Washington Acad. Sci., Jour., vol. 43, p. 176, pl. 2, figs. 1-2.; Malkin, 1953, Jour. Pal., vol. 27, p. 796, pl. 82, figs. 16-18.; Swain, 1955, *ibid.*, vol. 29, p. 635, pl. 62, figs. 3a-c.

Carapace small; thickest near the middle, greatest thickness being slightly less than one-half the length; highest at the anterior cardinal angle; in side view subovate. Dorsal margin faintly arched, ventral margin with a slight concavity near the middle; both margins converging posteriorly. Anterior end broadly rounded, dorsal portion oblique; posterior end narrow, compressed and with distinct angles where it meets the dorsal and ventral margins; both anterior and posterior ends possess a low, rounded rim. Surface of the valves reticulate, the reticulations being somewhat linear in arrangement. Interior of the valves deep, nearly smooth. The inner margin projects around the anterior, ventral and posterior ends, and the line of concrescence lies nearer the outer margin on the anterior end, and nearer the inner margin on the posterior end. The marginal area of the left valve possesses a faint groove into which is fitted a low, sharp ridge in the marginal area of the right valve. The ventral margins of both valves are slightly flanged just anterior to the middle. The hinge of the right valve consists of a large, high, knob-like tooth on the anterior end, behind which is a large broad pit, followed by a narrow groove which parallels the dorsal margin and is terminated at a large, oval, oblique, projecting tooth at the posterior cardinal angle. The hinge of the left valve consists of a deep, nearly circular socket, behind which is a low, broad, blunt tooth, the upper edge of which joins a low, sharp bar, which parallels the dorsal margin and which is separated from the dorsal margin by a broad, depressed area. The posterior end of the hinge is occupied by a large, shallow, oval socket. The muscle scar pattern is situated somewhat anterior to the middle of the carapace and consists of eleven, irregular, small, lucid spots. (Howe and McGuirt, 1935.)

Dimensions.—Length, 0.58 to 0.68 mm.; height, 0.34 mm. to 0.40 mm.; thickness, 0.26 mm.

Occurrence.—Carter's Grove; Moore House Beach; Camp Wallace; Ft. Eustis well at 135-160 ft.; Langley Field; Felgaters creek;

Remarks.—The Yorktown specimens were compared with topotypes furnished me by Dr. Howe, and, except for slight variations in the ornamentation, were found to be identical; many specimens were identical in ornamentation.

Family **CYTHERELLIDAE**

Genus **CYTHERELLA** Jones, 1849

Cytherella chipolensis Puri — Pl. 12, figs. 5a-b

Cytherella chipolensis Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 300-301, pl. 17, figs. 5-6, text figs. 14e-g.

Carapace medium, oblong in dorsal view; fusiform anteriorly; oblong-ovate in side view. Dorsal margin slightly arched; ventral margin slightly concave in the middle. Both the anterior and posterior ends broadly rounded. Posterior end conspicuously thicker in the female; not so in the male. Surface of the carapace smooth, porcellanous. Viewed from the inside, the valves are shallow. There are well-developed ventral and dorsal flanges. Both the anterior and posterior margins are very narrow; marginal pore canals not observed. (Puri, 1954.)

Dimensions.—Length, 0.659 mm.; height, 0.422 mm. (largest dimensions given).

Occurrence.—Fort Eustis well at 135 to 160 feet deep.

Remarks.—The single valve figured from the Ft. Eustis well is identical to a topotype furnished me by Howe, except that the topotype was the opposite valve. It seems diagnostic of the pre-Yorktown Miocene of Florida and Virginia.

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ERRATA

Page 64, line 25, read "below" for "above"

Page 85, line 25, read "*producta*" for "*products*"

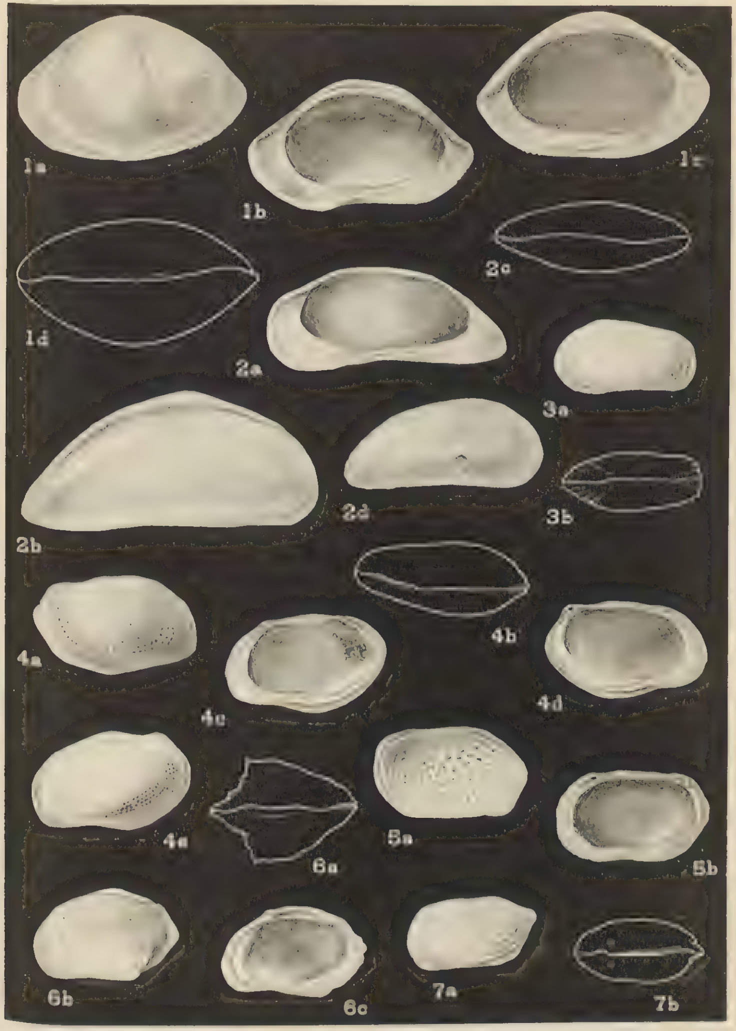
Page 99, line 3, read la-b for la b; read **"Clithrocytheridea"** for **"Clithroeytheridea"**

Explanation of Plate 7

Figure		Page
1a-d.	**Bairdoppilata triangulata** Edwards 1a, left valve exterior; 1c, left valve interior; 1b, right valve interior; 1d, dorsal view; all of P.R.I. No. 22,486 plesiotype.	69
2a-d.	**Paracypris choctawhatcheensis** Puri 2a, right valve interior; 2b, right valve exterior of two separate specimens on plesiotype slide P.R.I. No. 22,494; 2c, dorsal view; 2d, right valve of plesiotype P.R.I. No. 22,495.	70
3a-b.	**Cytheromorpha** cf. **warneri** Howe and Spurgeon 3a, exterior view, right valve; 3b, dorsal view, plesiotype P.R.I. No. 22,497.	70
4a-e.	**Loxoconcha purisubrhomboidea** Edwards 4a, exterior view of right valve; 4b, dorsal view of P.R.I. No. 22,499 plesiotype; 4c, interior view of right valve; 4d, interior view of left valve; 4e, exterior view of left valve of plesiotype P.R.I. No. 22,500.	71
5a-b.	**Loxoconcha reticularis** Edwards 5a, exterior view of right valve; 5b, interior view of right valve of plesiotype P.R.I. No. 22,504. (5a inverted)	72
6a-c.	**Cytheropteron talquinensis** Puri 6a, dorsal view; 6b, exterior view of right valve; 6c, interior view of left valve of plesiotype P.R.I. No. 22,506.	73
7a-b.	**Cytherura reticulata** Edwards 7a, exterior view right valve; 7b, dorsal view of plesiotype P.R.I. No. 22,509.	73

All magnifications of this and the following plates approximately 43.5×

PLATE 7


1a
1b
1c
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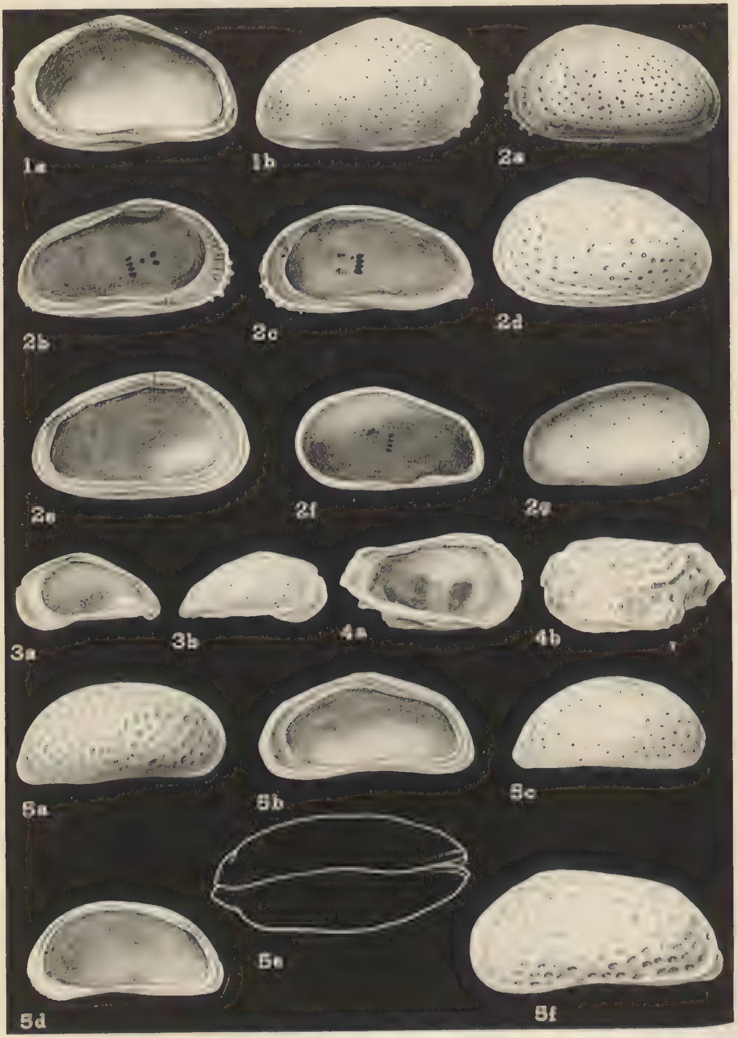
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EXPLANATION OF PLATE 8

Figure Page

1a b. **Clithrocytheridea diagonalis** Malkin 74
1a, interior view, right valve; 1b, exterior view of same valve, plesiotype P.R.I. No. 22,510. This species seems to be restricted to the pre-Yorktown and is here figured for comparison with *C. virginiensis.*

2a-g. **Clithrocytheridea virginiensis** Malkin 74
2a-c, interior and exterior views of valves of plesiotype P.R.I. No. 22,511 (2c right valve; 2a,b, left valve); 2d-e, exterior and interior views of left valve of plesiotype P.R.I. No. 22,512; 2 f-g, interior and exterior views of right valve of a juvenile form plesiotype P.R.I. No. 22,513.

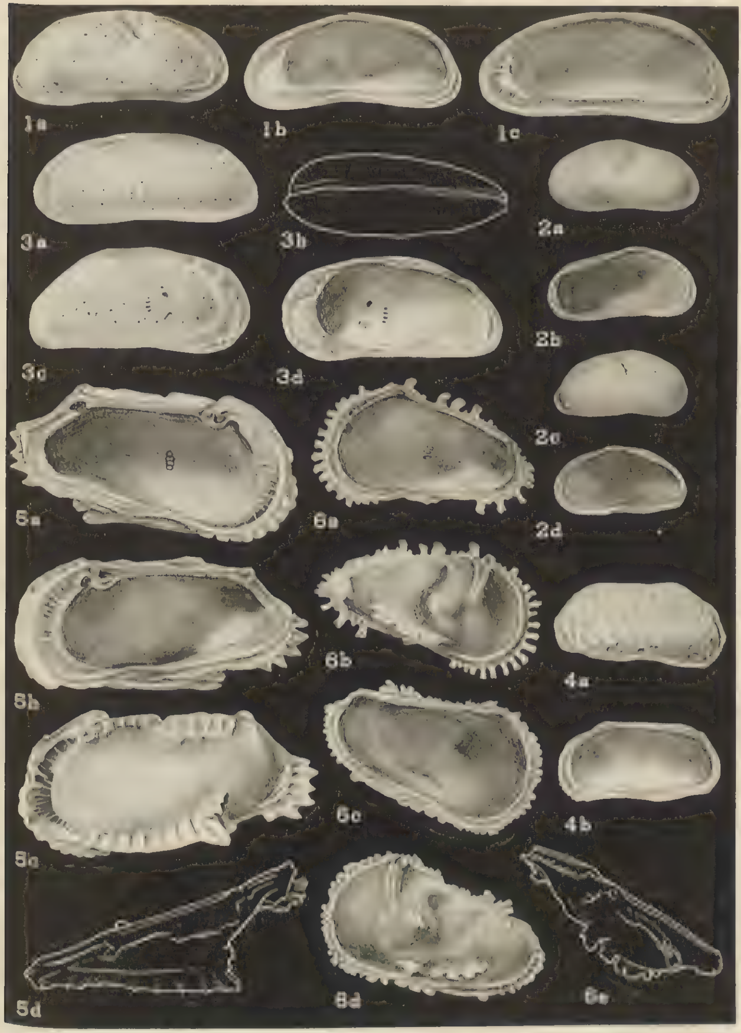
3a-b. **Eucythere** sp. 76
Interior and exterior views of P.R.I. No. 22,523, a single right valve which is the only specimen found of this small species.

4a-b. **Paracytheridea vandenboldi** Puri 75
Interior and exterior views of a single left valve plesiotype P.R.I. No. 22,524.

5a-f. **Cushmanidea ashermani** (Ulrich and Bassler) 77
5a, exterior view right valve; 5b, interior view same valve plesiotype P.R.I. No. 22,525; 5c, exterior view of right valve; 5d, interior view of same valve P.R.I. No. 22,526, this specimen has considerably finer ornamentation than usual; 5e, dorsal view; 5f, exterior view left valve P.R.I. No. 22,527.

EXPLANATION OF PLATE 9

Figure		Page
1a-c, 2a-d.	**Cushmanidea echolsae** (Malkin) 1a, exterior view of right valve; 1b, interior view of same valve; 1c, interior view of another valve showing variation of the form, both valves from slide P.R.I. No. 22,533; 2a-b, interior and exterior views of a left valve; 2c-d exterior—interior views of a left valve; both forms juvenile specimens, P.R.I. No. 22,534.	78
3a-d.	**Cushmanidea ulrichi** (Howe and Johnson) 3a, exterior view, left valve; 3b, dorsal view of plesiotype P.R.I. No. 22,538; 3c-d, exterior and interior views of right valve of plesiotype P.R.I. No. 22,539.	79
4a-b.	**Leguminocythereis (?) whitei** Swain Exterior and interior views of a right valve plesiotype P.R.I. No. 22,543.	80
5a-d, 6a-e.	**Pterygocythereis americana** (Ulrich and Bassler) 5a, interior view left valve; 5c, exterior view of same valve; 5b, interior view of right valve; 5d, dorsal view of left valve; all views from same specimen plesiotype P.R.I. No. 22,544; 6a-b interior and exterior views of a right valve of a juvenile form plesiotype P.R.I. No. 22,545; 6c-d, interior and exterior views of a right valve of a juvenile form; 6e, dorsal view of a left valve all from plesiotype slide P.R.I. No. 22,546.	80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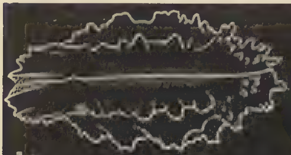
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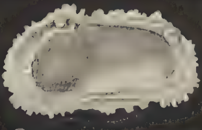
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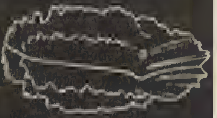
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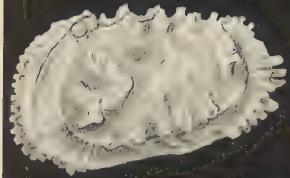
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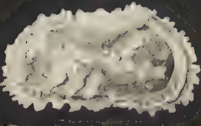
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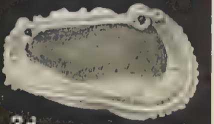
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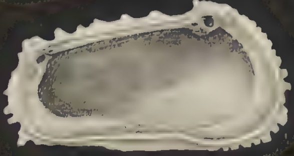
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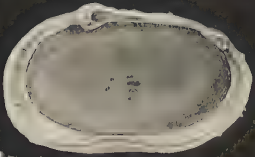
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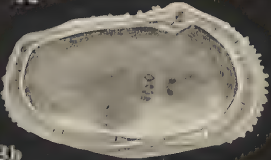
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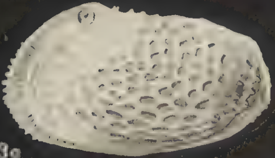
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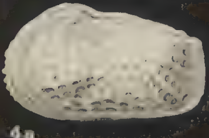
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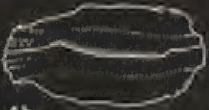
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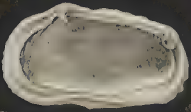
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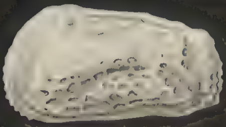
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Explanation of Plate 10

Figure Page

1a-c. **Actinocythereis exanthemata** (Ulrich and Bassler) 82
1a, dorsal view; 1b, exterior of left valve; 1c, interior of same left valve plesiotype P.R.I. No. 22,554.

2a-d. **Actinocythereis exanthemata gomillionensis** (Howe and Ellis) 83
2a, 2c, interior and exterior views of right valve; 2b, dorsal view; 2d, interior view of left valve; all views of plesiotype P.R.I. No. 22,559.

3a-c. **Echinocythereis clarkana** (Ulrich and Bassler) 84
3a, interior view of right valve; 3b, 3c, interior and exterior views of left valve; all views of plesiotype P.R.I. No. 22,569. The exterior of this species is covered with small spines that are not fully indicated by the figure of the exterior here pictured.

4a-e. **Murrayina howei** Puri 85
4a, exterior view of left valve; 4b, dorsal view, both views of plesiotype P.R.I. No. 22,572. 4c, interior view of a right valve; 4d, dorsal view; 4e, exterior view of a left valve, all views from plesiotype slide P.R.I. No. 22,571.

EXPLANATION OF PLATE 11

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1a-c, 2a-b, 3a-d.	**Murrayina martini** (Ulrich and Bassler) 1a, dorsal view; 1b, 1c, exterior and interior views of a right valve all of plesiotype P.R.I. No. 22,575. 2a, exterior view of a left valve; 2b, dorsal view, both of plesiotype P.R.I. No. 22,576; 3a, interior view of a right valve; 3b, dorsal view; 3c, 3d, exterior and interior views of a left valve, all of plesiotype P.R.I. No. 22,574. These figures show the variations common in this species.	86
4a-f.	**Murrayina barclayi** McLean, n. sp. 4a, 4b, exterior and interior views of right valve; 4c, interior view of same specimen left valve, all of holotype P.R.I. No. 22,588. 4d, 4f, exterior and interior views of left valve of juvenile form; 4e, interior view of right valve of same specimen, paratype P.R.I. No. 22,587.	87
5a-d.	**Puriana rugipunctata** (Ulrich and Bassler) 5a, exterior view of left valve; 5b, dorsal view of same specimen, plesiotype P.R.I. No. 22,596; 5c, 5d, exterior and interior views of left valve of a juvenile form plesiotype P.R.I. No. 22,597.	89
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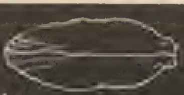
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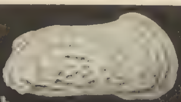
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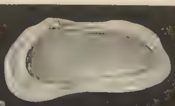
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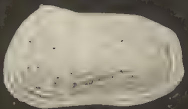
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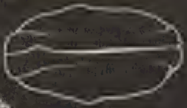
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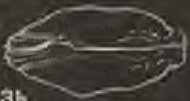
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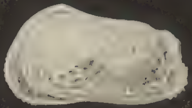
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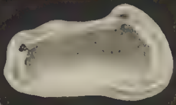
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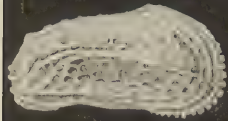
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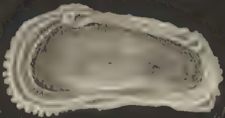
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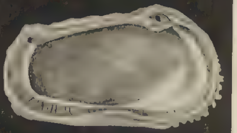
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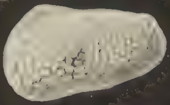
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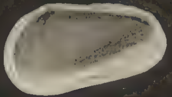
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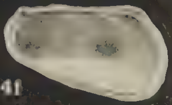
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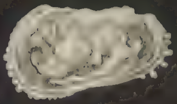
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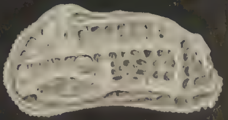
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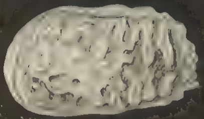
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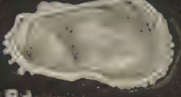
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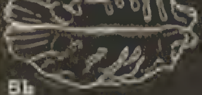
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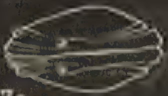
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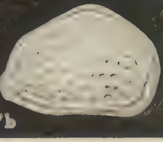
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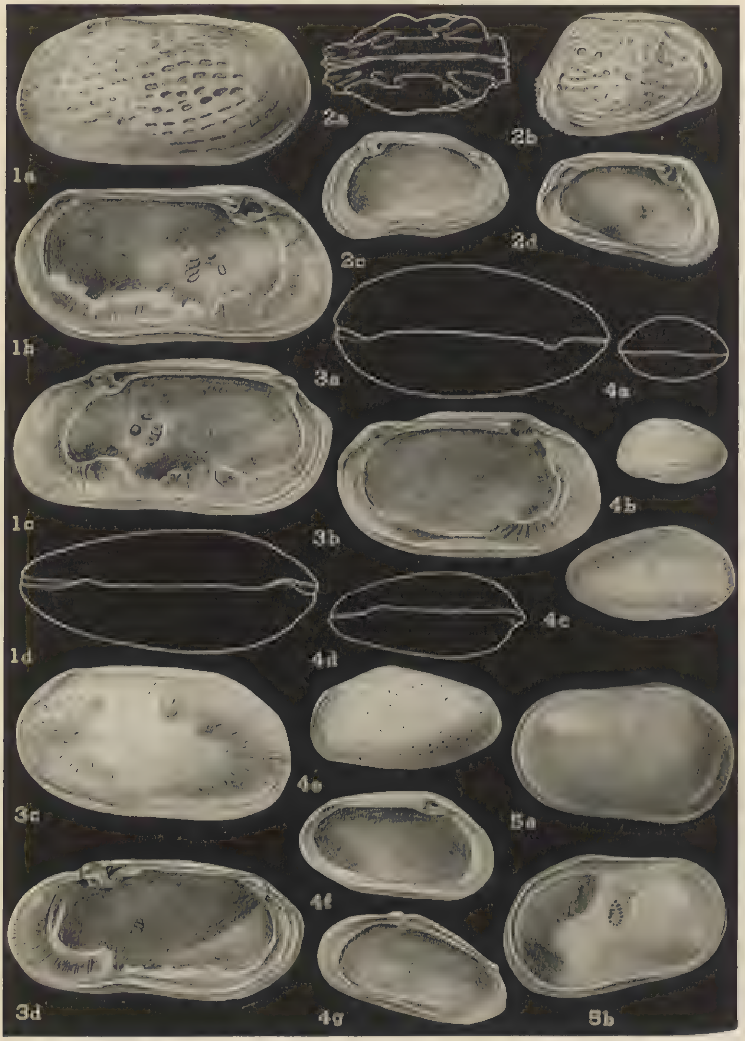
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EXPLANATION OF PLATE 12

Figure		Page
1a-d.	**Cytheretta burnsi** (Ulrich and Bassler) 1a, 1b, exterior and interior views of left valve; 1c, interior view of right valve; 1d, dorsal view, all from plesiotype slide P.R.I. No. 22,605.	91
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5a-b.	**Cytherella chipolensis** Puri Exterior and interior views of a single right valve plesiotype P.R.I. No. 22,645.	95

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STRATIGRAPHY OF THE NEW PROVIDENCE FORMATION (MISSISSIPPIAN) IN JEFFERSON AND BULLITT COUNTIES, KENTUCKY, AND FAUNA OF THE CORAL RIDGE MEMBER

By

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August 10, 1957

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STRATIGRAPHY OF THE NEW PROVIDENCE FORMATION (MISSISSIPPIAN) IN JEFFERSON AND BULLITT COUNTIES, KENTUCKY, AND FAUNA OF THE CORAL RIDGE MEMBER

JAMES E. CONKIN

Department of Geology and Geography, University of Cincinnati

ABSTRACT

The Silver Hills facies of the New Providence formation in Jefferson and Bullitt counties, Kentucky, is divided into three members: New Providence formation

- Kenwood sandstone member (of Stockdale)—containing the *Productus wortheni* zone.
- Button Mold Knob member (new stratigraphic name)—divided into upper, middle, and lower parts—containing the Button Mold Knob fauna.
- Coral Ridge member (new stratigraphic name)—divided into upper and lower parts—containing the Coral Ridge fauna in the upper part.

The recognition of the herein proposed *Productus wortheni* zone, Button Mold Knob fauna, and Coral Ridge fauna, allows more detailed and practical stratigraphic division of the New Providence formation in the Silver Hills facies than has previously been possible.

In the upper part of the Coral Ridge member, the writer found the unique and heretofore unknown megafossil fauna, the Coral Ridge fauna. This fauna is of primary importance for understanding age relationships of the Lower Mississippian of Kentucky and Indiana, and for comparison of the Lower Mississippian succession of North America with the Lower Carboniferous deposits in Europe.

The fossils of the Coral Ridge fauna are pyritized, marcasitized, or silicified, and consist dominantly of mollusks, with some blastoids, crinoids, corals, and trilobites. Thirty-two genera are recognized.

Fossils judged to be of primary importance for age determination of the Coral Ridge fauna are: the goniatites, *Pericyclus*, *Beyrichoceras*, and *Merocanites*; the blastoid, *Orbitremites*, and the crinoid, *Wachsmuthicrinus*.

The first undoubted specimens of *Pericyclus* from North America are herein recorded from the Coral Ridge fauna.

Information derived from a consideration of the geologic ranges of the genera and species of the Coral Ridge fauna, coupled with the stratigraphic position of the fauna (20 to 30 feet below the lower Osagian so-called "Fern Glen-Burlington" correlative in the New Providence formation, the Button Mold Knob member), proves that the age of the Coral Ridge is Osagian. The Coral Ridge fauna is slightly older than previously known faunas which have been referred to the Osagian of North America and slightly younger than previously known faunas which have been referred to the upper Kinderhookian of North America. Thus the lower age limit of the New Providence formation is lowest Osagian.

The age of the lower part of the Coral Ridge member is not determined, whether Kinderhookian or Osagian, as no megafossils have been found in this part of the member.

Two new species of gastropods, *Bembexia ellenae* and *Sinuitina anneae*, and two new species of blastoids, *Orbitremites coralridgensis* and *O. kentuckyensis*, are described, and the description of one species, *O. oppelti*, is emended.

INTRODUCTION

PURPOSE

This paper presents the results of a stratigraphic and paleontologic study of the Silver Hills facies of the New Providence formation in Jefferson and Bullitt counties, Kentucky. Emphasis is placed upon the proposed division of the Silver Hills facies into three members each with its distinctive fauna. Particular attention is given to the description of the singular and heretofore unknown fauna, the Coral Ridge fauna, from the upper part of the Coral Ridge member (of this paper) of the New Providence formation. The Coral Ridge fauna is of primary importance for understanding age relationships of stratigraphic units within the Lower Mississippian succession of Kentucky and Indiana and for correlation of the Lower Mississippian of North America with the Lower Carboniferous deposits in Europe.

PREVIOUS WORK

The Lower Mississippian of Kentucky and Indiana has long been subject to stratigraphic study, but little effort has been expended upon paleontologic aspects of the series. A detailed account of the history of division and classification of the Lower Mississippian (including the New Providence formation) in Indiana and Kentucky was given by Stockdale in 1931 (pp. 11-44) and 1939 (pp. 7-33).

The New Providence "shale" was so named by Borden in 1874 (p. 161) from a locality near the town of Borden, then New Providence, in Clark County, Indiana. However, the classic collecting localities for the formation are at Button Mold Knob in Bullitt County, Kentucky, and Kenwood Hill in Jefferson County, Kentucky.

In 1931, Stockdale changed the name of the New Providence shale to the New Providence formation, and he divided the formation in Indiana into three facies: Broomhill facies, Dowell Hill facies, both in Indiana; and Silver Hills facies of Floyd County, Indiana, with its extension into Jefferson County, Kentucky.

In his comprehensive work of 1939, Stockdale extended his investigations throughout Kentucky and divided the New Providence formation into nine facies; some of the facies were further divided into named members. The Silver Hills facies was extended into northern Bullitt County, Kentucky.

The Silver Hills facies differs from Stockdale's type facies of the New Providence formation (Broomhill facies, from Broomhill in southwestern Clark County, Indiana) by the presence of the Kenwood sandstone member in the uppermost part of the Silver Hills facies. In 1931 (p. 94) and 1939 (pp. 110, 111) Stockdale stated that the Kenwood sandstone extends only a few miles northward into Indiana and southward only to about Shepherdsville in Bullitt County, Kentucky; he concluded that the Kenwood sandstone was not a separate formation as proposed by Butts (1915, p. 148), but only a member of the New Providence formation in the Silver Hills facies.

The age of the New Providence formation has been accepted by most recent workers as Osagian (Fern Glen-Burlington), based on the Button Mold Knob fauna from the well-known crinoidal bioherms and fossiliferous shales in the Button Mold Knob member (of this paper) of the formation.

Campbell (1946, p. 905) noted that evidence is lacking for either an Osagian or Kinderhookian age for the lower shales (which would be the herein proposed Coral Ridge member), and he indicated the inadvisability of assuming the New Providence formation to be a single stratigraphic unit. J. M. Weller, *et al.* (1948, Chart 5) placed the New Providence formation mostly in the Osagian, but indicated the possibility of a Kinderhookian age for part of the lower New Providence formation.

Recently two important papers concerning Lower Mississippian faunas have appeared. The posthumus work of Hyde, edited by Marple (1953), presented the only recent attempt at comprehensive stratigraphic and faunal coverage of the Lower Mississippian of Ohio. Miller and Garner's (1955) report is the first up-to-date publication on the cephalopods of the Coldwater and Marshall formations of Michigan. Both the Coldwater and Marshall formations and the Lower Mississippian of Ohio contain faunas with close affinities to each other and to the Coral Ridge fauna.

PRESENT WORK

The Silver Hills facies of the New Providence formation in Jefferson and northern Bullitt counties is included in this study. Only minor structures are present within the studied area so that for purposes of this investigation the New Providence formation may be considered nearly independent of structural influence.

Sections in the studied area which reveal the nature of the New Providence formation were measured and collections of fossils were made from

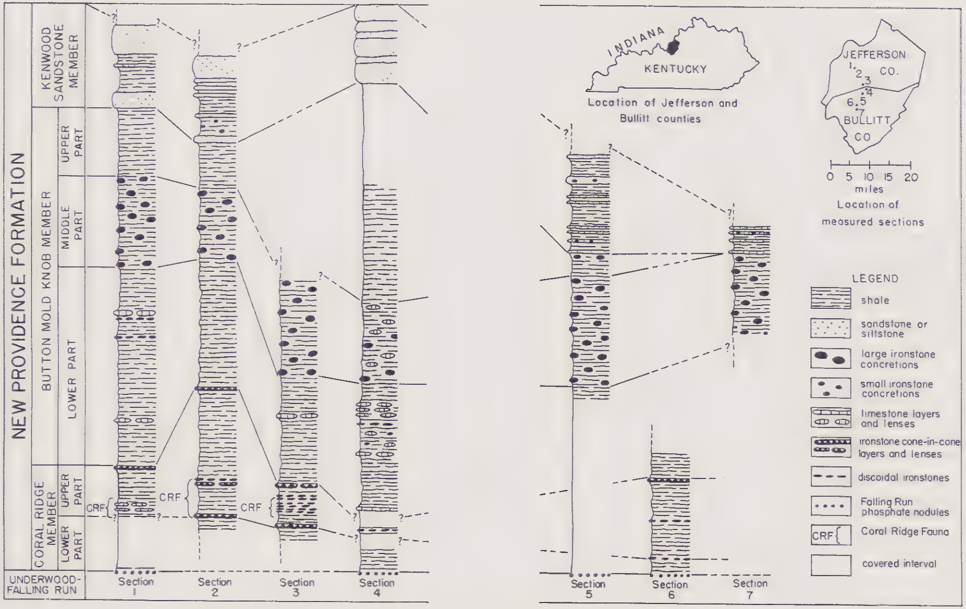

NEW PROVIDENCE FORMATION
KENWOOD SANDSTONE MEMBER
BUTTON MOLD KNOB MEMBER
UPPER PART
MIDDLE PART
LOWER PART
CORAL RIDGE MEMBER
UPPER PART
LOWER PART
UNDERWOOD-FALLING RUN
CRF
Section 1
Section 2
Section 3
Section 4
Section 5
Section 6
Section 7
INDIANA
KENTUCKY
Location of Jefferson and Bullitt counties
JEFFERSON CO.
BULLITT CO
1 2 3 4 5 6 7
0 5 10 15 20
miles
Location of measured sections
LEGEND
shale
sandstone or siltstone
large ironstone concretions
small ironstone concretions
limestone layers and lenses
ironstone cone-in-cone layers and lenses
discoidal ironstones
Falling Run phosphate nodules
Coral Ridge Fauna
covered interval

Chart 1.—Columnar sections of the New Providence formation in Jefferson and Bullitt counties, Kentucky (Vertical Scale—¼" = approximately 15') the critical upper part of the Coral Ridge member. The best available datum for comparison of sections was judged to be a zone of greenish-gray shale and phosphatic nodules constituting the Underwood-Falling Run interval (Campbell, 1946) which underlies the New Providence formation and overlies the black New Albany shale in this part of Kentucky.

The measured sections and the columnar sections (Chart 1) indicate irregularity of the New Providence sedimentation, but these sections also call attention to natural stratigraphic units into which the New Providence formation is divisable in the Silver Hills facies area. Differentiation of the formation into members and parts of members, and the recognition of definite faunal divisions, as proposed in this paper allow more accurate stratigraphic placement of sections in outcrop and afford a means of tracing individual parts of the formation in the field. No two of the measured sections were found to have all members and parts of members and all faunal elements at the same levels above the Underwood-Falling Run interval; in some sections certain parts of the members are present in abbreviated form.

The dominantly molluscan Coral Ridge fauna, which begins about 20 feet above the top of the Underwood-Falling Run interval, was found by the writer in the upper part of the Coral Ridge member at Coral Ridge and Kenwood Hill in Jefferson County, Kentucky. Description and discussion of this fauna comprise the paleontologic portion of this paper. All recognized new species of fossils are described with the exception of the goniatites which have been turned over to Drs. A. K. Miller and William Furnish of the University of Iowa for description.

The Coral Ridge member in the Silver Hills facies in Floyd and Clark counties, Indiana, should be searched for possible occurrences of the Coral Ridge fauna. That the fauna may be present in these counties is suggested by the report of *Orbitremites oppelti* Rowley in the Knobstone shale north of New Albany, Indiana (Greene, 1902, p. 87). Further, Springer reported (1912, p. 205) specimens of *Orbitremites granulatus* (Roemer) ". . . direct from the Knobstone shale at Stone's Farm, Clark County, Indiana, in layers 40 to 50 feet above the 'Black Slate'."

ACKNOWLEDGMENTS

This study in thesis form was accepted as partial fulfillment of the degree of Master of Science at the University of Kansas in 1953; further work on the paper has continued up to the present time.

The writer is grateful to Dr. R. C. Moore for his valued aid in directing the thesis. The writer is also happy to acknowledge the help of the following: Dr. K. E. Caster, who aided in later stages of development of the manuscript for publication; Drs. Arthur Bowsher and G. A. Cooper who encouraged the writer to finish the work for publication; Mr. Guy Campbell who critically read the manuscript and made helpful suggestions based on his wide knowledge of Lower Mississippian stratigraphy; Prof. Robert O. Fay who aided with the photography; Dr. J. Brookes Knight who gave helpful aid on the gastropods; Dr. L. R. Laudon who checked the writer's determinations of the crinoids; Mrs. Mildred Fisher Marple who loaned some of Hyde's types for study; Dr. A. K. Miller who identified the goniatites; and especially Mrs. Barbara Conkin who prepared the plates and figures, and who aided with constructive criticism of the manuscript.

The cost of illustrations has been met by The Faber Fund for Paleontologic Research of the University of Cincinnati Geology Museum.

STRATIGRAPHY

PROPOSED DIVISION OF THE NEW PROVIDENCE FORMATION IN THE SILVER HILLS FACIES IN KENTUCKY

The division of the New Providence formation in the Silver Hills facies in Kentucky into three members, and the division of two of these members into parts is proposed as follows:

- New Providence formation—Silver Hills facies
  - Kenwood sandstone member (*Productus wortheni* zone)
  - Button Mold Knob member
    - Upper part (rare Button Mold Knob fauna)
    - Middle part (Button Mold Knob fauna)
    - Lower part (Button Mold Knob fauna)
  - Coral Ridge member
    - Upper part (Coral Ridge fauna)
    - Lower part (no megafossil fauna)

The new stratigraphic names introduced in this paper are the Button Mold Knob member and the Coral Ridge member. The name Kenwood sandstone member (type locality at Kenwood Hill) has already been applied to the upper sandstones, siltstones, and intercalated shales of the Silver Hills facies by Stockdale.

The type locality for the Button Mold Knob member is herein designated as the well-known, fossiliferous outcrop of the New Providence formation at Button Mold Knob, Bullitt County, Kentucky. Only the lower and middle parts of the Button Mold Knob member are well exposed at the type locality. The upper, middle, and lower parts of the member are well developed and exposed at Kenwood Hill, Jefferson County, Kentucky.

The type locality for the Coral Ridge member is herein designated as the east quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky. The upper part of the member is best developed at Coral Ridge. Approximately the basal half of the lower part of the member is covered at the type locality. More complete sections of the lower part of the Coral Ridge member can be seen at the Button Mold Knob and B. C. Miller's Farm sections (Sections 4 and 6).

The most complete section of the New Providence formation in the studied area is at Kenwood Hill where all individual members and parts of members can be seen, with the exception of the lower part of the Coral Ridge member which was exposed in an excavation in 1951. The Button Mold Knob fauna and the Coral Ridge fauna are also well developed at Kenwood Hill. Were it not for the facts that the Button Mold Knob fauna is irrevocably and justifiably associated with the Button Mold Knob locality in Bullitt County, and that the Coral Ridge fauna is best developed at the Coral Ridge locality, Kenwood Hill would have made a good type locality for the proposed division of the New Providence formation.

The division of the New Providence formation in the Silver Hills facies area is based on lithology as well as on the contained faunas.

The Kenwood sandstone member is lithologically distinct and also contains a brachiopod-fucoid fauna, hereby designated the *Productus wortheni* zone. This zone contains *P. wortheni*, the fucoid *Taonurus caudigalli*, and worm tubes.

The Button Mold Knob member contains the Button Mold Knob fauna which has given the "Fern Glen-Burlington" age to this portion of the formation. The term Button Mold Knob fauna is hereby proposed; the fauna is typically developed at Button Mold Knob. Characteristic fossils of the fauna are:

Amplexus fragilis, Cladochonus sp., *Cyathaxonia* spp.,*Platycrinus* spp., *Synbathocrinus* spp., *Fenestrellina* spp., *Rhombopora incrassata, Athyris lamellosa, Chonetes shumardianus, Rhipidomella oweni, Spiriferina subelliptica, Platyceras* sp., *Phillipsia* sp., *Taonurus caudigalli*, and other fucoids.

The Coral Ridge member contains in its upper part the Coral Ridge fauna which is named from Coral Ridge. The Coral Ridge fauna is shown in this paper to be low Osagian.

All members proposed in this paper can be recognized in the Silver Hills facies type locality area in Floyd County, Indiana.

A summary description of the proposed division of the New Providence formation based on all measured outcrops in the Silver Hills facies in Kentucky, follows:

- New Providence formation—Silver Hills facies
  - Kenwood sandstone member
    - Sandstone, siltstone, and intercalated green-gray shale, with ironstone concretions; *Productus wortheni* zone
  - Button Mold Knob member
    - Upper part
      - Shale, green-gray, with rare ironstone concretions; Button Mold Knob fauna rare
    - Middle part
      - Shale, green-gray, with large-to medium-sized ironstone concretions, some limestone and ironstone lenses; Button Mold Knob fauna
    - Lower part
      - Shale, green-gray in upper portion, becoming blue-gray in lower portion, fossiliferous, crinoidal bioherms, ironstone lenses, rare and smaller ironstone nodules; Button Mold Knob fauna
  - Coral Ridge member
    - Upper part
      - Shale, green-gray to blue-gray, with ironstone lenses, ironstone cone-in-cones, flat, variously shaped, dark gray to blue-gray, small ironstone nodules, some phosphatic nodules, rare and thin ferruginous and fossiliferous limestone lenses; pyritized, marcasitized, and rarely silicified, Coral Ridge fauna
    - Lower part
      - Shale, green-gray, virtually free of ironstones of even the smallest size, with worm markings; no megafossils noted

MEASURED SECTIONS

Section 1. Kenwood Hill, north and northwest sides, southern Louisville, Jefferson County, Kentucky

This is a composite section and the most complete section of the New Providence formation measured in the studied area. The lithologic variation of the New Providence formation may be seen at Kenwood Hill. On the north and northwest sides of the hill the Button Mold Knob member contains numerous fossiliferous limestone lenses with the Button Mold Knob fauna; on the south side, the limestone lenses are absent and there only two crinoid columnals were found during an intensive search of the Button Mold Knob member.

New Providence formation
Kenwood sandstone member
Top few feet of member covered

	Thickness	
	Feet	Inches
36. Sandstone, buff	12	0
35. Shale, olive-gray	4	8
34. Sandstone, buff, upper half with worm markings, lower half with ironstone septarians	0	7
33. Shale, olive-gray	10	5
32. Sandstone, buff, with ironstained concretionary rings	6	6
	34	2
Button Mold Knob member		
Upper part		
31. Shale, olive-gray, gray-green near bottom	27	1
Middle part		
30. Shale, pale olive, with ironstone concretions; no fossils	21	8
29. Shale, pale olive, with ironstone concretions; first fossil, one crinoid columnal, top of Button Mold Knob fauna	2	0
28. Shale, olive-gray, with ironstone concretions and rare crinoid stems	13	4
	37	0
Lower part		
27. Shale, olive-gray; rare crinoid stems and *Rhipidomella oweni*	0	8
26. Shale, olive-gray; frequent crinoid stems and *R. oweni*	3	9
25. Shale, olive-gray; crinoid stems and rare *R. oweni*	1	8
24. Shale, olive-gray; crinoid stems and rare to frequent *R. oweni*	12	1
23. Shale, olive-gray; crinoidal limestone, with *Platyceras* sp., *Cyathaxonia* sp., and fragments of pectinate bivalves and bryozoans	0	3
22. Shale, olive-gray; crinoid stems and other fossils	0	1.5
21. Ironstone lenses, containing crinoid stems and brachiopods	0	0.5
20. Shale, olive-gray; crinoid stems, brachiopods, and bryozoans	5	3.5
19. Shale, olive-gray; crinoid stems	3	0
18. Ironstone lenses; crinoid stems	0	3

	Thickness	
	Feet	Inches
17. Shale, olive-gray; crinoid stems, fragments of *Brachythyris orbicularis*	8	5
16. Shale, olive-gray; crinoid stems	24	11
15. Limestone lens, crinoidal	0	4
14. Shale, olive-gray; crinoid stems; base of observed Button Mold Knob fauna	1	0
13. Covered interval	10	10
12. Shale, olive-gray	8	5
	81	0.5
Coral Ridge member		
Upper part		
11. Shale, olive-gray, with silicified cone-in-cone structures	0	0.5
10. Shale, olive-gray; no fossils	13	3
9. Shale, olive-gray; one *Beyrichoceras* sp.; top of Coral Ridge fauna	0	6
8. Limestone lens, ferruginous and crinoidal; Coral Ridge fauna	0	2
7. Shale, olive-gray; worm markings and Coral Ridge fauna	1	7
6. Limestone lens, phosphatic; Coral Ridge fauna	0	0.5
5. Shale, olive-gray; worm markings and Coral Ridge fauna	1	3
4. Shale, olive-gray; Coral Ridge fauna	1	10
3. Shale, olive-gray, mixed with colluvium; base of visible Coral Ridge fauna	0	6
	19	2
Lower part		
2. Covered interval	21	3
1. Shale, olive-gray	0	10
	22	1
Datum: Underwood-Falling Run interval; shale, gray to olive-gray, with phosphatic nodules		
total	220	6.5

Section 2. Kenwood Hill, south side, southern Louisville, Jefferson County, Kentucky

New Providence formation

Kenwood sandstone member	Thickness	
Top few feet of member covered.	Feet	Inches
25. Sandstone, massive, gray-green to buff, partly covered at top; fucoids	10	0
24. Sandstone, massive, gray-green to buff, medium-grained, with ironstone concretions and septarians; fucoids	1	8
23. Shale, olive-gray	1	0
22. Sandstone, massive, buff, with fewer ironstone concretions	2	2
21. Shale, olive-gray	0	6
20. Sandstone, massive, buff, medium-grained, with ironstone septarian band through middle of bed; fucoids abundant	1	4
19. Shale, olive-gray, a few limonite concretions; fucoids	6	5
18. Sandstone, buff, with ironstone septarians; fucoids	1	0
17. Shale, olive-gray, with ironstone concretions; fucoids	7	6
16. Sandstone, buff	3	5
	35	0

	Thickness	
	Feet	Inches
Button Mold Knob member		
Upper part		
15. Shale, olive-gray; fucoids	17	9
Middle part		
14. Shale, bluish-gray, numerous medium and large ironstone concretions up to 1.5 feet in diameter; no fossils	28	1
Lower part		
13. Shale, bluish-gray; first fossil, one crinoid columnal	5	5
12. Shale, bluish-gray; no fossils	27	1
11. Shale, bluish-gray, small ironstone concretions; no fossils	9	11
10. Shale, bluish-gray, becoming bluer downward	10	0
	52	5
Coral Ridge member		
Upper part		
9. Ironstone cone-in-cone lenses locally developed	0	2
8. Shale, purer, plastic, bluish-gray, with few ironstone concretions	27	1
7. Shale, bluish-gray; no fossils	8	3
6. Shale, gray-blue; one coral and one conularid in ironstone nodules; top of observed Coral Ridge fauna	0	11
5. Ironstone cone-in-cone, locally developed	1	1
4. Shale, bluish-gray; Coral Ridge fauna	9	11
3. Shale, olive-gray; Coral Ridge fauna consisting of rare *Bembexia ellenae*	1	6
2. Shale, olive-gray, with ironstone cone-in-cone; Coral Ridge fauna: *Bembexia ellenae, Retispira?* sp.	3	6
	52	5
Lower part		
1. Shale, olive-gray; no fossils; remainder of lower part covered	4	0
total	189	8

Section 3. East quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky

This is the type locality for the Coral Ridge member of the New Providence formation and for the Coral Ridge fauna.

The middle part of the Button Mold Knob member contains a trilobite zone about 85 to 87 feet above the base of the exposed section, dominated by *Phillipsia* sp., with lesser numbers of *Griffithides* sp.

The west quarry of the brick company has its floor in the upper zone of large ironstone cone-in-cones (bed. 13), but no element of the Coral Ridge fauna has been found there. The west quarry floor barely reaches the upper part of the Coral Ridge member, so it is probable that the Coral Ridge fauna is present a few feet below the surface of the floor.

	Thickness	
	Feet	Inches
New Providence formation		
Button Mold Knob member		
Middle part		
Top of section covered.		
19. Shale, olive-gray, with ironstone concretions and rare fossils of the Button Mold Knob fauna; beds slumped, measurement unreliable	12	0
18. Shale, olive-gray, large ironstone concretions; fewer fossils than in bed 17	26	5
	38	5
Lower part		
17. Shale, olive-gray, fossiliferous; abundant crinoid stems	15	10
16. Limestone, crinoidal	0	7
15. Shale, olive-gray, fossiliferous; abundant crinoid stems	3	0
14. Shale, gray, partly covered	24	8
	44	1
Coral Ridge member		
Upper part		
13. Shale, bluish-gray, with lenses of double cone-in-cones of ironstone, 5 inches thick; top of Coral Ridge fauna	4	6
12. Shale, bluish-gray, with a thin bed of ironstone lenses; Coral Ridge fauna	1	0
11. Ironstone lenses, source of some fossils of Coral Ridge fauna	0	0.5
10. Shale, bluish-gray; fossils	2	6.5
9. Shale, bluish-gray, with bed of thin ironstone lenses; throughout this unit there are many large to medium-sized geodized corals, their subsurface position marked on the surface by streaks of yellow hydrated marcasite	1	0
8. Shale, bluish-gray with thin bed of ironstone lenses	0	0.5
7. Shale, bluish-gray, with bed of 0.5 inch thick discoidal ironstone nodules; geodized corals	1	0
6. Shale, bluish-gray, with a thin bed of discoidal ironstone nodules; fossils in nodules and in shale	0	6
5. Shale, bluish-gray, with yellow streaks on surface marking subsurface position of marcasitized *Bembexia ellenae*; base of observed Coral Ridge fauna	1	11.5
4. Shale, bluish-gray	3	0
3. Ironstone cone-in-cone	0	3.5
	15	10.5
Lower part		
2. Shale, bluish-gray	5	9
1. Covered interval, not measured		
total	104	1.5

Section 4. Button Mold Knob, one mile south of the Jefferson County-Bullitt County line, Bullitt County, Kentucky

This is the classic locality from which most of the fossil collections from the New Providence formation have been made. The Button Mold Knob fauna is widely known and is of primary importance for correlation of the Button Mold Knob member of the formation. There should be a detailed restudy made of the Button Mold Knob fauna.

This is also the type locality for the Button Mold Knob member.

The Coral Ridge fauna disappears somewhere between the Coral Ridge and Button Mold Knob sections which are about one mile apart. Rare, platey shaped, small to medium-sized, gray ironstone nodules are found about 16 feet 8 inches above the Underwood-Falling Run interval. These nodules are characteristic of the upper part of the Coral Ridge member at Coral Ridge and Kenwood Hill.

New Providence formation	Thickness	
Kenwood sandstone member	Feet	Inches
19. Sandstone and siltstone	33	0
Button Mold Knob member		
Upper part		
18. Shale, partly covered in upper portion; rare Button Mold Knob fauna	91	0
Middle part		
17. Shale, pale olive, with scattered limestone patches; Button Mold Knob fauna	16	0
16. Shale, pale olive, with crinoidal limestone patches, large ironstones; *Aulopora* sp. frequent	16	5
	32	5
Lower part		
15. Shale, pale olive, fossiliferous	10	3.5
14. Limestone lens, crinoidal, with bryozoans and *Aulopora* sp.	0	3.5
13. Shale, pale olive, fossiliferous	1	5
12. Limestone lens, crinoidal	0	5
11. Shale, pale olive, fossiliferous	1	1
10. Limestone lens, crinoidal	0	5
9. Shale, pale olive, crinoidal	3	6
8. Ironstone lens	0	3
7. Shale, pale olive, with ironstones; crinoidal limestone lenses up to 2 feet thick	11	9
6. Shale, gray-green; at top is a crinoidal limestone lens with *Rhipidomella oweni*	21	1
5. Limestone, crinoidal, with calcareous olive-green shale with crinoids and other fossils	1	1
	51	7
Coral Ridge member		
Upper part		
4. Covered interval	8	0
3. Shale, olive-gray, with platey ironstone nodules (lithologic associate of Coral Ridge fauna); no fossils	0	4
2. Covered interval	7	9
	16	1
Lower part		
1. Shale, pale olive; no fossils	8	11
total	233	0

Datum: Underwood-Falling Run interval

Section 5. Brooks Hill, immediately west of Brooks, 2.5 miles southwest of Button Mold Knob, Bullitt County, Kentucky

	Thickness	
	Feet	Inches
New Providence formation		
Kenwood sandstone member		
16. Sandstone, greenish-gray	0	3.5
15. Shale, greenish-gray	9	0
14. Siltstone, with large ironstone concretions	3	0
13. Shale, greenish-gray, with four thin sandstone layers	22	2
12. Sandstone, yellowish-gray	0	2
11. Shale, greenish-gray	1	0
10. Sandstone, dusty yellow	0	2.5
9. Shale, greenish-gray	3	0
8. Siltstone, with ironstone layer	0	2.5
7. Shale, greenish-gray, with a few ironstones	3	0
6. Sandstone, greenish-gray to yellow-brown, medium-grained	0	6
	39	6.5
Button Mold Knob member		
Upper part		
5. Shale, greenish-gray, with large ironstones	2	0
4. Shale, greenish-gray	7	0
	9	0
Middle part		
3. Shale, greenish-gray, with large ironstones; shale becoming more silty upward to top of section	45	0
Lower part		
2. Shale, greenish-gray	4	0
1. Covered interval	71	0
total	168	6.5

Datum: top of Underwood-Falling Run interval

Section 6. B. C. Miller's farm, one mile north of Bullitt Lick Church on secondary road leading to Bullitt Lick School, Bullitt County, Kentucky

The Falling Run nodules crop out in the hog lot of the Miller farm. The lower part of the Coral Ridge member is exposed in this section.

	Thickness	
New Providence formation		
Button Mold Knob member	Feet	Inches
Lower part		
Upper portion covered and not measured.		
7. Shale, olive-gray to bluish-gray	10	3.5
Coral Ridge member		
Upper part		
6. Ironstone double cone-in-cone lenses	0	5.5
5. Shale, bluish-gray	15	2.5
4. Ironstone lenses	0	0.5
3. Shale, bluish-gray	16	10.5
2. Ironstone lenses	0	0.5
	32	7.5
Lower part		
1. Shale, bluish-gray	5	7
total	48	6

Datum: Underwood-Falling Run interval

At Coral Ridge and Kenwood Hill this upper part of the Coral Ridge member contains the Coral Ridge fauna. The geographic restriction of the fauna to southwestern Jefferson County and the rapid change in the nature of the New Providence sediments indicate that only small niches were suitable for invertebrate life (excepting foraminifers and sponges, Conkin, 1956) on the bottom of the lower New Providence sea in this part of Kentucky. The dominantly molluscan aspect of the Coral Ridge fauna suggests a shallow sea environment of deposition.

The lower part of the Button Mold Knob member, which carries the best development of the typical fauna, is at Button Mold Knob in Bullitt County. Fossiliferous shale and crinoidal bioherms are developed in the lower part of the Button Mold Knob member in all the sections in Jefferson County with the exception of that at the south side of Kenwood Hill. This lower part of the member does not contain fossils in the section exposed at B. C. Miller's farm (Section 6) near Shepherdsville, Bullitt County.

Section 7. Bullitt Lick Church, first road cut into the front of the Mississippian escarpment, 2.7 miles west of Shepherdsville on Kentucky Highway 44, Bullitt County, Kentucky

Gradational contact with Brodhead formation
New Providence formation

	Thickness	
	Feet	Inches
Kenwood sandstone member		
11. Siltstone, buff; possible top of New Providence formation	0	2.5
10. Shale, bluish-gray	0	9
9. Siltstone, buff, with ironstone concretions through center of bed	1	9
8. Shale, bluish-gray	1	4
7. Siltstone, buff	0	7
6. Shale, bluish-gray	5	0
5. Siltstone, buff	0	8.5
	10	4
Button Mold Knob member		
Upper and middle parts undifferentiated.		
4. Shale, bluish-gray, with ironstones	16	2
3. Ironstone concretions, discoidal, up to 3 feet in diameter	0	6.5
2. Shale, bluish-gray, with some large ironstone concretions	10	10
1. Shale, bluish-gray, with a few ironstones	5	5
	32	11.5
total	43	3.5

STRATIGRAPHIC CONCLUSIONS BASED ON MEASURED SECTIONS

The lower part of the Coral Ridge member is present throughout the studied area, but is best seen in outcrop at the B. C. Miller's farm section (Section 6). No megafossils were found in this lower part, and thus its age, whether Osagian or Kinderhookian, is uncertain.

The upper part of the Coral Ridge member is present throughout the studied area, although at Button Mold Knob it is present only as a remnant in the form of a thin bed of discoidal ironstone nodules in shale exposed about 16 feet 8 inches above the Underwood-Falling Run interval. The upper part of the Coral Ridge member in Jefferson County, Kentucky, and in the Goetz Quarry in the northwestern part of New Albany, Floyd County, Indiana, can be recognized by the presence of the large double cone-in-cone lenses of ironstone, and discoidal ironstone nodules. The cone-in-cones in the upper part of the Coral Ridge member are unique in that they have the characteristic cone-in-cone structures developed on both the lower and the upper surfaces of the lenses with the inner portion free of any secondary disturbance in most instances; these unique cone-in-cones are herein termed "double cone-in-cones". The cone-in-cones are not seen at Button Mold Knob, but they are weakly developed at the B. C. Miller's farm section near Shepherdsville, Bullitt County.

The middle part of the Button Mold Knob member is present throughout the studied area. The Button Mold Knob fauna is present in this unit in the sections at the north side of Kenwood Hill, Coral Ridge, and Button Mold Knob, but is absent in the Brooks Hill and Bullitt Lick Church sections (Sections 5 and 7).

The upper part of the Button Mold Knob member is noted at Brooks Hill where the presence of large ironstone concretions in this upper part of the member shows that here the contact between the upper and middle parts of the member is not sharp. This upper part cannot be differentiated from the middle part of the member in the Bullitt Lick Church section where together they consist of green-gray shale with ironstone lenses and large ironstone concretions. The Button Mold Knob fauna was observed in the upper part of the Button Mold Knob member only at Button Mold Knob.

The Kenwood sandstone member extends southward to Shepherdsville in Bullitt County; beyond Shepherdsville this member loses its identity and the sandstone grades upward into the Brodhead siltstones, as is seen in the Bullitt Lick Church section, making the contact between the New Providence formation and the Brodhead formation obscure.

PALEONTOLOGY

COMPOSITION OF THE CORAL RIDGE FAUNA

The Coral Ridge fauna has been found only at two localities, Kenwood Hill and Coral Ridge, both in Jefferson County, Kentucky. Variation in the distribution of the genera and species of the Coral Ridge fauna at the two localities is shown in Table 1.

Common genera in the Coral Ridge fauna at Coral Ridge, in order of their abundance, are: *Bembexia, Amplexus, Pericyclus, Sinuitina, Loxonema, Merocanites, Nuculana, Michelinoceras, Orbitremites, Phillipsia, Rhynchopora, Conocardium, Spiriferina, Griffithides, Favosites, Beyrichoceras, Conularia, and Striatopora* (*Acaciapora*).

Common genera in the Coral Ridge fauna at Kenwood Hill, in order of their abundance, are: *Bembexia, Pericyclus, Amplexus, Merocanites, Sinuitina, Nuculana, Beyrichoceras, Conocardium, Retispira?, Michelinoceras, Grammysia?,* and *Conularia.*

The Coral Ridge fauna at the type locality is richer in variety and more prolific in number of specimens than it is at Kenwood Hill.

Of the fossils listed in the faunal list (Table 1) only new species (except new species of goniatites) and *Orbitremites oppelti* Rowley are described and figured in this paper.

RANGE OF THE GENERA IN NORTH AMERICA

Many genera of the Coral Ridge fauna have long stratigraphic ranges; the following are known to range throughout the entire Mississippian in North America and thus have little value in age determination.

Corals: *Favosites, Michelinia, Neozaphrentis,* and *Striatopora*
Bryozoans: *Rhombopora*
Brachiopods: *Eumetria, Girtyella, Rhipidomella, Rhynchopora,* and *Spiriferina*
Pelecypods: *Conocardium and Nuculana*
Gastropods: *Loxonema* (or related genus; *Loxonema, s. s.,* may range only into the Lower Mississippian)
Cephalopods: *Michelinoceras*
Trilobites: *Griffithides*
Uncertain position: *Conularia*

Table 1.—Fossils in the Coral Ridge Fauna at Coral Ridge and Kenwood Hill Localities

Faunal List	Coral Ridge	Kenwood Hill
Amplexus fragilis	X	X
Favosites divergens	X	
Michelinia sp.	X	
Neozaphrentis sp.	X	X
Striatopora (Acaciapora) sp.		X
Rhombopora incrassata		X
Cyrtina sp.	X	
Eumetria sp.	X	
Girtyella sp.	X	
Rhipidomella sp.		X
Rhynchopora beecheri	X	
Spiriferina subelliptica	X	
Spiriferina sp.	X	
Conocardium cancellatum	X	X
Edmondia? sp.	X	X
Grammysia? sp.	X	X
Nuculana sp.	X	X
Bembexia ellenae, n. sp.	X	X
Loxonema delphicola	X	X
Orthonynchia sp.	X	X
Retispira? sp.	X	X

Table 1.—(Continued)

Faunal List	Coral Ridge	Kenwood Hill
Sinuitina anneae, n. sp.	X	X
Beyrichoceras sp.	X	X
Merocanites sp.	X	X
Michelinoceras sp.	X	X
Pericyclus sp.	X	X
Codaster jessieae	X	
Orbitremites coralridgensis, n. sp.	X	
O. kentuckyensis, n. sp.	X	
O. oppelti, emend.	X	
Synbathocrinus cf. S. dentatus	X	
Wachsmuthicrinus sp.	X	
Griffithides sp.	X	
Phillipsia sp.	X	
Conularia sp.	X	X

The North American stratigraphic ranges, known previous to this paper, of the genera which are important for age determination of the Coral Ridge fauna are listed in Table 2, in terms of the type Mississippian section in North America.

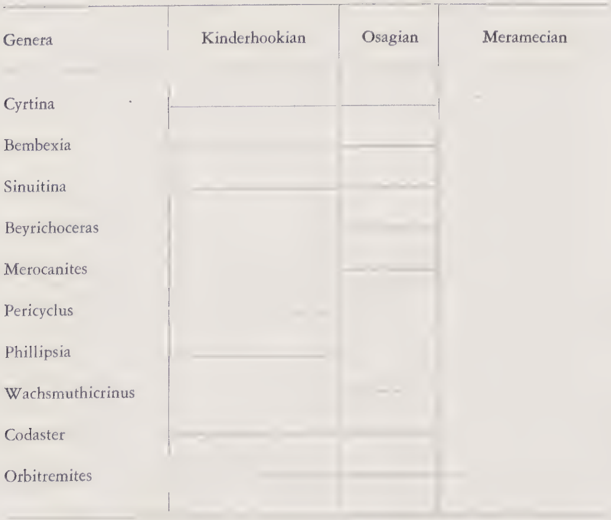
The goniatites, blastoids, and the crinoid *Wachsmuthicrinus* are of first value in age determination. The trilobite *Phillipsia,* the gastropods *Bembexia* and *Sinuitina,* and the brachiopod *Cyrtina* are of secondary importance. *Loxonema* was thought by Knight (1930, p. 4) to range no higher than the Devonian. As the nuclear whorls are not preserved in the present specimens it is uncertain whether the Coral Ridge individuals should be referred to *Loxonema, s. s.*

Reviewing the North American occurrences of the genera of goniatites present in the Coral Ridge fauna, it is noted that the Coral Ridge fauna contains the first undoubted specimens of *Pericyclus* yet reported from North America. *Pericyclus? blairi* (Miller and Gurley) (Miller and Youngquist, 1947, p. 115) has been recorded from both the Caballero formation (Kinderhookian) of New Mexico and the Chouteau limestone (Kinderhookian) of Missouri.

Beyrichoceras is known in North America from *B. hornerae* Miller (1947, p. 21) apparently from the Boone chert (Osagian) of Missouri and from *B. allei* Miller and Garner (1955, pp. 144-149) from both the Coldwater and Marshall formations (Osagian) of Michigan.

Merocanites is known from North America from *M.* sp. (Miller and Garner, 1955, p. 154) from the Reeds Spring limestone of Missouri; from

Table 2.—North American Mississippian Ranges of Genera Important for Age Determination of the Coral Ridge fauna



M. houghtoni Miller and Garner (1955, pp. 150-154) and from *M. marshallensis* Miller and Garner (1955, pp. 154-157) both from the Coldwater and Marshall formations of Michigan. Collinson (1955, pp. 434-436) described *M. drostei* from the Brodhead formation of Madison County, Kentucky.

Among the blastoids, *Orbitremites* is characteristically an Osagian genus (especially prominent in the Burlington limestone) ; one species, *O. chouteauensis* Peck (1938, p. 69) is known from the Chouteau limestone (Kinderhookian) of Missouri; one doubtful species, *O. grandis* Rowley (Greene, 1902, p. 97) is known from the Fort Payne formation (Osagian, and probably partly Meramecian) of Kentucky.

Codaster, characteristically a Devonian blastoid genus, ranges throughout the Kinderhookian and Osagian.

Wachsmuthicrinus is restricted to the *Osagian.*

Among the fossils judged to be of secondary importance in age determination, the trilobite *Phillipsia,* as emended by Weller (1936, pp. 704-706) is a Lower Mississippian genus (Kinderhookian) ; although, as unrestricted, the genus has been reported in the Upper Mississippian and the Pennsylvanian of North America.

Bembexia is characteristically a Devonian genus occurring particularly in the beds of the Hamilton group, but the genus ranges into the lower part of the Mississippian, and also occurs in the Logan formation of Ohio (Osagian).

Sinuitina is recorded by Hyde (Marple, 1953, pp. 319, 320) as *Tropidodiscus* from the Bedford shale (Kinderhookian) and the Byer member of the Logan formation (Osagian) of Ohio. The type species of *Sinuitina* is from the Pennsylvanian of Oklahoma.

As for the range of *Cyrtina*, Stuart Weller said (1914, p. 286) that the ". . . genus *Cyrtina* has its greatest development in the Devonian faunas, being represented in only the earlier portion of Mississippian time." Weller gave the range of *Cyrtina* as Louisiana limestone to Keokuk.

RANGE OF THE GENERA IN THE EUROPEAN SECTION

The Dinantian section of Europe is subdivided into faunal zones defined by cephalopods, corals, and brachiopods (see Chart 2).

A review of the stratigraphic ranges of important genera of the Coral Ridge fauna in terms of the European section is given here.

Orbitremites: undifferentiated Viséan.
Codaster: Tournasian and Viséan.
Wachsmuthicrinus: upper Tournasian.
Pericyclus: late Tournasian (C sub zones) (II α and II β); lower Viséan (C_2 and S_1) (II γ and II δ).
Beyrichoceras and *Merocanites*: middle Viséan (S_2 and D_1) (B_1 and B_2) and lower part of (III).

Moore (1948, pp. 397-400) has observed:

> The zone of *Beyrichoceras* is very clearly established in western Europe, both in the British Isles and on the Continent, as middle Viséan in age (figs. 1, 15, 16). Beds belonging to this zone and containing its diagnostic fossils have been found to interfinger with strata of the coral-brachiopod zones in a manner to show that the B_1 subzone corresponds to the S_2 subzone containing numerous *Lithostrotion* and other characteristic Upper Mississippian corals, brachiopods, and other fossils (Hudson and Turner, 1933a); the B_2 subzone is found to correspond in age to the D_1 subzone, which very surely is not older than Meramecian deposits of North America and possibly belongs to the Lower Chesterian. Discovery of representatives of *Beyrichoceras* in Osagian rocks of North America, as reported by Miller (1947), constitutes the record of a single identification of a representative of this genus in a stratigraphic position that can hardly fail to be far below that of the *Beyrichoceras* zone as defined in Europe. *Beyrichoceras* may have become differentiated as a genus in Tournasian time, and the region in which it first became differentiated is unknown. As pointed out by Miller, the distinction between *Beyrichoceras* and *Muensteroceras* is extremely small, and the latter genus is very well developed in Tournasian deposits. Overwhelming evidence supplied by crinoids, echinoids, brachiopods, corals, and probably other fossils, is utterly in conflict with the supposition that the European D zone can possibly be equivalent to pre-Meramecian deposits of North America. It is unfortunate that, as yet, numerous representatives of the European D zone have not been found on the western side of the Atlantic. Until such evidence is found, the record of *Beyrichoceras* in early Mississippian rocks of this continent cannot be permitted to outweigh abundant evidence of a differing sort.

Since 1948, the presence of *Beyrichoceras* and *Merocanites* in the Lower Mississippian of North America has been established. Thus, as far as present records are valid, it seems certain that both *Beyrichoceras* and *Merocanites* were differentiated earlier in North America than in Europe; or as Miller and Garner (1955, p. 119) suggest,

> The upper Tournasian of Belgium carries *Imitoceras rotatorium*, several species of *Münsteroceras*, and *Protocanites lyoni*, just as does the upper Kinderhook Rockford limestone of Indiana. It seems logical to correlate these strata from opposite sides of the Atlantic, even though the European beds have not yet yielded *Prodromites*, which is a characteristic and striking form in the Rockford and in the stratigraphically equivalent strata in Missouri, Iowa, and Illinois. Acceptance of such a correlation leads to the conclusion that in the European section the approximate correlative of the Mississippian goniatite-bearing beds of Michigan is the lower Viséan. (*Imitoceras*, *Münsteroceras*, *Beyrichoceras*, and *Merocanites* all occur in the lower Viséan, together with

> *Pericyclus*, which, as we interpret that genus, is not present in Michigan). If this conclusion is correct, the American Osage strata are the approximate stratigraphic equivalent of the European lower Viséan, rather than of the upper Tournasian, as commonly stated. We are, of course, not the first to advocate this view.

Miller and Garner continue (1955, p. 120),

> In Middle Asia (north Kazakhstan) Librovitch (1940) recognized several Carboniferous "cephalopod complexes". One, the oldest of these "complexes", contains representatives of *Gattendorfia, Kazakhstania, Imitoceras, Karagandoceras,* and the species *Protocanites lyoni*; and it is to be correlated in a general way with the fauna of the American upper Kinderhook. The second of Librovitch's Kazakhstanian "complexes" consists of species belonging in *Münsteroceras, Pericyclus,* and probably *Merocanites*; it presumably does not differ

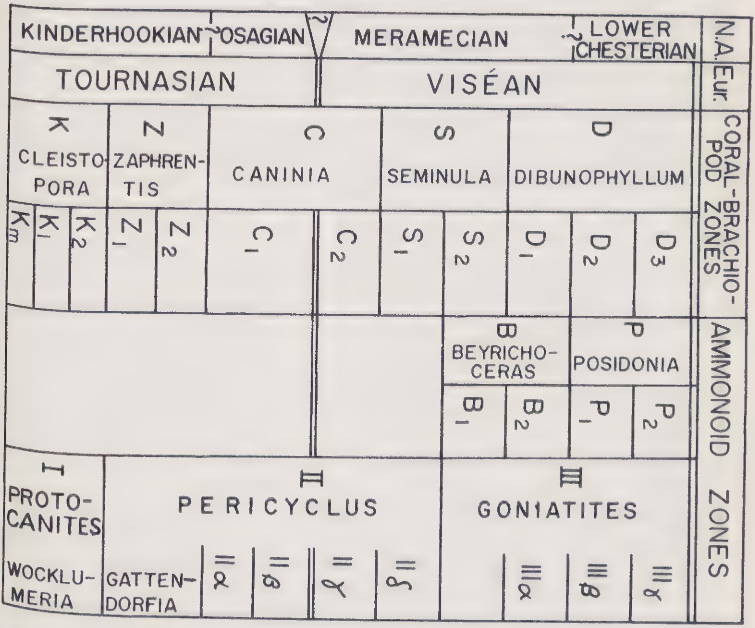

KINDERHOOKIAN
?
OSAGIAN
?
MERAMECIAN
?
LOWER CHESTERIAN
N.A.
TOURNASIAN
VISÉAN
Eur.
K
CLEISTOPORA
Z
ZAPHRENTIS
C
CANINIA
S
SEMINULA
D
DIBUNOPHYLLUM
CORAL-BRACHIOPOD ZONES
Km
K1
K2
Z1
Z2
C1
C2
S1
S2
D1
D2
D3
B
BEYRICHOCERAS
P
POSIDONIA
B1
B2
P1
P2
AMMONOID ZONES
I
PROTOCANITES
II
PERICYCLUS
III
GONIATITES
WOCKLUMERIA
GATTENDORFIA
IIα
IIβ
IIγ
IIδ
IIIα
IIIβ
IIIγ

Chart 2.—Comparison of part of the North American Mississippian with part of the European Lower Carboniferous (after Moore, 1948, p. 375, fig. 1)

> greatly in age from the Lower Mississippian Michigan fauna we are studying. To the east, in the Tien Shan, there occurs a prolific goniatite fauna that contains a variety of representatives of *Pericyclus* in association with *Münsteroceras* and *Merocanites*; it also seems to be about the same general age as the Michigan assemblage. Librovitch, however, was inclined to place the Kazakhstanian "complex" containing *Merocanites* in the upper Tournasian and the Tien Shan fauna in the lower Viséan.

Pericyclus, although previously known in North America from only the Kinderhookian, is associated in the Coral Ridge fauna with definitive Osagian cephalopod, blastoid, and crinoid genera. Although *Pericyclus* is known from the upper Tournasian of Europe, its characteristic occurrence there is in the lower Viséan. *Pericyclus* may have appeared earlier in North America (upper Kinderhookian) than in Europe (upper Tournasian).

Among the blastoids, *Orbitremites* is known from Europe from the undifferentiated Viséan. With the exception of the somewhat doubtful *O. grandis* Rowley (described from a cast in the Fort Payne chert of Kentucky —Osagian and probably partly Meramecian), *Orbitremites* has not been recorded above the Osagian. *O. chouteauensis* Peck constitutes the only record of the genus in the Kinderhookian rocks of North America. Thus it also seems that *Orbitremites* arose earlier (Kinderhookian) in North America than in Europe (undifferentiated Viséan).

AGE OF THE CORAL RIDGE FAUNA

In conclusion, the age aspect of important genera in the Coral Ridge fauna is as follows:

Genus	Known Range in N. A. (prior to this paper)	Known Range in Europe
Pericyclus	upper Kinderhookian	upper Tournasian, but especially lower Viséan
Beyrichoceras and *Merocanites*	lower to middle Osagian	middle Viséan
Codaster	Kinderhookian and Osagian	Tournasian and Viséan
Orbitremites	upper Kinderhookian, Osagian, and probably lower Meramecian	undifferentiated Viséan
Wachsmuthicrinus	Osagian	upper Tournasian

When considered from a specific point of view, the geologic ranges of the fossils of the Coral Ridge fauna center around the Kinderhookian-Osagian boundary.

Information derived from a consideration of the geologic ranges of the genera and species in the Coral Ridge fauna, coupled with the stratigraphic position of the fauna (20 to 30 feet below the lower Osagian so-called "Fern Glen-Burlington" correlative in the New Providence formation, the Button Mold Knob member) proves that the age of the Coral Ridge fauna is Osagian. The Coral Ridge fauna is slightly older than previously known faunas which have been referred to the Osagian of North America and slightly younger than previously know faunas which have been referred to the upper Kinderhookian of North America.

CORRELATION OF THE NEW PROVIDENCE FORMATION

The present state of knowledge of the New Providence formation indicates the following correlation based on other studies and on the paleontologic and stratigraphic information presented in this paper (Chart 3).

SYSTEMATIC PART

BLASTOIDS

The species of *Orbitremites* from the Coral Ridge fauna possess all typical characters of the genus: a deep basal concavity, two hydrospire folds under each ambulacrum, hydrospire pores throughout the entire length of the ambulacrum, radials longer than deltoids, and five spiracles with one spiracle piercing the apex of each deltoid.

Ornamentation is highly organized on the *Orbitremites* from the Coral Ridge fauna. Prominent ridges are developed on the radials parallel to the radial deltoid suture and the interradial suture; these ridges are herein termed "dalaths" after their resemblance to the Hebrew letter dalath. There are V-shaped ridges on the deltoids parallel to the radial deltoid suture, and these ridges are herein termed "chevrons" after their resemblance to chevrons. Etheridge and Carpenter (1886, p. 249) noted the alignment of nodes and tubercles (to form dalaths) on certain species of Lower Carboniferous *Orbitremites,* such as *O. campanulatus* of the British Isles. Dalaths and chevrons are well developed on some species of *Cryptoblastus* which thus superficially resemble some species of *Orbitremites.*

Specimens of each species of *Orbitremites* from the Coral Ridge fauna were sectioned and two hydrospire folds were noted under each ambulacrum. The presence of two hydrospire folds under each ambulacrum is characteristic of the genus. Among all the known species of *Orbitremites* which have been sectioned only one exception is known, *O. norwoodi,* which has four hydrospire folds under each ambulacrum. This observation casts suspicion on the relationship of *O. norwoodi* to true *Orbitremites*; the solution to this problem must await a synthesis of the genus *Orbitremites* along the line of Cline's papers on *Schizoblastus* (1936, pp. 260-281) and *Cryptoblastus* (1937, pp. 634-649).

Chart 3. Correlation of the New Providence formation

SERIES	CORRELATIVES	NEW PROVIDENCE FORMATION
OSAGIAN	Keokuk?-Burlington?	Kenwood sandstone member (*Productus wortheni* zone)
	"Burlington-Fern Glen"	Button Mold Knob member Upper part (rare Button Mold Knob fauna) Middle part (Button Mold Knob fauna) Lower part (Button Mold Knob fauna)
LOW OSAGIAN		Coral Ridge member Upper part (Coral Ridge fauna)
OSAGIAN OR KINDERHOOKIAN		Coral Ridge member Lower part (no megafossils noted; age uncertain)

The characters herein used in specific differentiation within the genus *Orbitremites* in the Coral Ridge fauna are: 1) shape of the calyx (ratio of height to width correlated with the apparent age of the individuals), 2) shape of the ambulacra, 3) amount of depression of the ambulacra below the surface of the calyx, 4) ornamentation (number of dalaths and chevrons, and size and arrangement of tubercles), 5) manner of formation of the ambulacral pores, and 6) shape of the spiracles.

Three species of *Orbitremites* are recognized from the Coral Ridge fauna of the upper part of the Coral Ridge member of the New Providence formation of Jefferson County, Kentucky; they are:

Orbitremites coralridgensis Conkin, n. sp.
Orbitremites kentuckyensis Conkin, n. sp.
Orbitremites oppelti Rowley, emend. Conkin

Genus **ORBITREMITES** Austin and Austin, 1840

Orbitremites kentuckyensis Conkin, n. sp. Pl. 13, figs. 1-20; Text-figs. 1-B, 1-C, 1-E

Description.—Calyx subglobose, slightly flattened at summit; height, 8.0 to 18.2 mm.; greatest width (caused by expansion of upper one-third of deltoids) at mid-height of calyx, 9.4 to 21.7 mm.; cross section circular on any plane above radial deltoid suture (if sunken ambulacral areas are disregarded), but polygonal on any plane transverse to radials because of sulci developed by lateral union of slightly convex radials; prominent dalaths and chevrons; five spiracles; radials and deltoids subequal in height.

A detailed description of the holotype follows:

Five elongate, slitlike spiracles; apices of deltoids moderately depressed, but only slightly below level of ambulacrum; at apex of each visible deltoid is an elongate depression leading into the spiracles; length of deltoids ranges from 8.5 to 10.7 mm.; dorsad to apical depression are a number of somewhat irregularly spaced tubercles belonging on a few fused chevrons; below these fused chevrons is a well-defined and raised chevron, 1.5 to 2.0 mm. wide, bearing tubercles in two nearly regular rows; this chevron is succeeded dorsally by another well-defined chevron, 1.0 to 1.5 mm. wide, which bears 5 to 7 tubercles in a single row with a single medium-sized tubercle above the tubercle at apex of chevron; slight variation noted in size of deltoids; largest deltoid may represent anal deltoid; however, as there is no recognized anal spiracle and basals are not seen, correct orientation of calyx is not possible.

Radial deltoid suture and interradial suture form three angles of 120 degrees each.

Radials are 12.9 mm. long, 11.3 mm. wide at radial deltoid suture, and 5.5 mm. wide at basal concavity; radials turn inward at base to aid in formation of basal concavity; radials bordered by a row of tubercles on each ambulacral edge; each half of radials on each side of ambulacrum has four well-defined delaths ornamented with tubercles (with an additional two or more dalaths fused and obscured): the first well-defined dalath bears one row of 10 tubercles; the second dalath (formed by the fusion of two major and one minor dalaths) is a raised ridge bearing about 14-17 tubercles; the third distinct dalath is as broad as the second distinct dalath but less raised and bears about 10-12 tubercles; the fourth distinct dalath is broad and bears up to 30 tubercles.

Basals deeply incurved and not visable in side view; outline of basal concavity is pentagonal.

The ambulacrum extends entire length of calyx; ambulacral area is 1.2 mm. wide at summit, 2.2 mm. wide at radial deltoid suture, and 1.0 mm. wide at base; ambulacrum projects slightly over basal concavity; lancet plates scarcely visible; side plates preserved, about 13 in 5 mm.; hydrospire pores present throughout entire length of ambulacrum, and formed mostly in outer side plates but partly in deltoids; two hydrospire folds present, one under each half of ambulacrum; in horizontal sections taken at radial deltoid suture, stalks of hydrospire folds form sigmoidal curves and bear pyriform hydrospire sacs (see Text-figs.1-B, 1-C, and 1-E of sectioned paratypes).

For a detailed analysis of the seven paratypes of *Orbitremites kentuckyensis*, see Table 3.

Remarks.—Orbitremites kentuckyensis varies in several ways. There is a slight variation in the ratio of height to width as shown in the measurements of the holotype and unfigured paratype No. 1. This unfigured paratype is more oblate than the holotype and the other paratypes.

There is a varying number of dalaths on the radials and a varying number of chevrons on the deltoids. There seems not to be a gradual increase in the number of chevrons and dalaths with growth of the blastoids; however, the true picture is obscured because of the fusion of two or more chevrons, or two or more dalaths, at varying growth stages of the calyx.

There is a variance in size of the basal concavity.

Table 3.- Detailed analysis of three species of *Orbitremites* (measurements in millemeters)

Specimen and U.S.N.M. No.	Shape of calyx	Height of calyx	Width of calyx	Length of deltoids	Width of deltoids	Sculpture on deltoids (V = chevron)	Angles at radial-deltoid suture	Length of radials at right posterior radial	Width of radials	Sculpture of radials (D = dalath)	Amount of depression of deltoids at apex	Base	No. of side plates in 5 mm. of ambulacral length and total no. of side plates	Width of ambulacrum at radial-deltoid suture	Formation of pores	Summit	Size of tubercles	Shape of ambulacrum	Amount of depression of ambulacrum below surface	Shape of spiracles
O. coralridgensis, holotype, 127324, sectioned	melon-shaped, prolate	12.0	11.1	6.5	4.7	13 V's with rare and subdivided tubercles	132 center, 114 left, 114 right	8.0	6.4	11 D's, no tubercles	posterior ? one raised, rest deeply depressed	deep, with round column, 3.6	14 - 36	1.8	in outer side plates	depressed	rather rare, subdued, smooth tubercles	broader in middle, petaloid	elevated near apex and at base	posterior one broadly elongate
O. oppelti, hypotype, 127323, sectioned	melon-shaped, subglobose	24.0	25.0	13.7	12.5	14 V's and tubercles	134 center, 113 left, 113 right	16.4	13.2	about 10 D's and 4 depressed bands	slightly raised above ambulacrum	deep, fairly narrow, 6.4	13.5 - 67	2.4 at right posterior ambulacrum	apparently in outer side plates and deltoids	slightly depressed	large	linear	only very moderately depressed	obscure, but two are apparently slit-like
O. cf. *O. oppelti*, hypotype, 127322; now nearly destroyed	subglobose	15.0	15.0	6.3	7.4	11 V's and tubercles	131 center, 112 left, 117 right	6.5	9.0	7 slender D's, and tubercles	somewhat depressed, but not below ambulacrum	deep, fairly narrow	13 - 39	2.0	in outer side plates, relation to deltoids obscure	ditto	moderately large	linear	moderately depressed	elongate slit
O. kentuckyensis, holotype, 127316	subglobose	18.2	20.8	10.7	8.5	4 V's and tubercles, minor V fused	120 center, 120 left, 120 right	12.9	11.3	6 D's, 2 minor ones fused, tubercles	apices moderately depressed	deep, broader, 9.5	13 - 45.5	2.2	in outer side plates and deltoids	ditto	very large	linear, comparatively narrow	deeply depressed	elongate slit
O. kentuckyensis, unfigured paratype 1, retained by writer	slightly more oblate than holotype	15.8	20.6	11.2	8.5	6 V's, 3 minor V's and tubercles	117 center, 123 left, 120 right	11.9	11.0	ditto	ditto	deep, fairly narrow, 6.0	13 - 41	2.2	in outer side plates, relation to deltoids obscure	ditto	large	ditto	ditto	obscure, apparently slit-like
O. kentuckyensis, paratype, 127317	subglobose	11.7	14.6	7.7	6.6	4 V's fused and tubercles	122 center, 120 left, 119 right	8.7	8.0	4 D's and trace of 5, tubercles	depressed, but not below ambulacrum	deep, broad, 5.4	14 - 30	1.9	in outer side plates and deltoids	ditto	fairly large	broader in middle	moderately depressed	ditto
O. kentuckyensis, paratype, 127318	subglobose	10.0	10.5	6.1	4.8	5 V's, 2 minor ones and tubercles	137 center, 113 left, 110 right	8.0	6.2	5 D's and few tubercles	somewhat depressed, but not below ambulacrum	deep, moderately broad, 3.7	15 - 30	1.2	ditto	ditto	ditto	ditto	ditto	ditto
O. kentuckyensis, paratype, 127319	subglobose	9.6	11.2 distorted	5.6	5.1	10 V's; no tubercles preserved (cast)	140 center, 110 left, 110 right	6.7	5.9	8 D's, no tubercles, (cast)	ditto	deep, distorted, broad, 4.6	16 - 31	1.6	ditto	ditto	cast; tubercles not preserved	ditto, distorted	ditto	obscure
O. kentuckyensis, paratype, 127320	subglobose	14.0	17.0	8.3	8.1	not preserved	obscured	9.0	10.0	none preserved	ditto	deep, fairly broad, 6.6	not preserved	1.7	in outer side plates, relation to deltoids obscure	ditto	ditto	linear, but broader at apex	ditto	ditto
O. kentuckyensis, unfigured paratype 2, retained by writer	subglobose	8.0	9.4	4.7	3.4	2 V's and tubercles	121 center, 116 left, 123 right	5.5	4.9	2 D's and tubercles	raised above ambulacrum	moderately deep and broad, 3.1	14 - 22	1.5	ditto	ditto	moderately large	broader near middle	ditto	elongate slit

Seemingly there is a tendency toward fewer side plates per unit ambulacral length in the larger specimens. Smaller specimens possess 14-16 side plates per 5 mm. whereas larger specimens possess 13-15 side plates per 5 mm.

Although ambulacral width becomes slightly greater with increase in size of the specimens, the ambulacrum become more linear in outline in the large specimens.

Orbitremites kentuckyensis is similar to *O. granulatus* (Roemer) in the shape of the calyx and the possession of a profusion of tubercles, but in contrast to *O. granulatus* the calyx of *O. kentuckyensis* is more oblate and the ornamentation of *O. kentuckyensis* is highly organized into chevrons and dalaths.

The affinities of *Orbitremites kentuckyensis* to the doubtful *O. grandis* Rowley (Greene, 1902, p. 96) cannot be determined as *O. grandis* is a cast.

Orbitremites kentuckyensis is somewhat similar to *O. chouteauensis* Peck but is specifically distinct in that *O. kentuckyensis* possesses strongly developed dalaths, tuberculated calyx, and moderately inflated radials.

Deposition of types.—The holotype, U. S. N. M., No. 127316, and five figured paratypes, U. S. N. M., Nos. 127317-127321, are deposited in the U. S. National Museum in Washington, D. C.

Occurrence.—The holotype and all paratypes are derived from the Coral Ridge fauna of the upper part of the Coral Ridge member of the New Providence formation, in the east quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky.

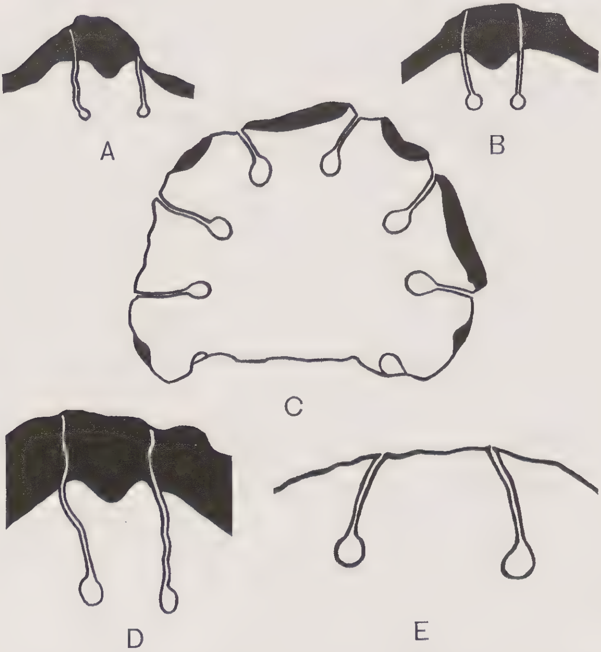
Orbitremites coralridgensis Conkin, n. sp. Pl. 14, figs. 8-11; Text-fig. 1-A

Description.—Calyx melon-shaped (prolate); greatest length, 12.0 mm.; greatest width, 11.1 mm.; cross section polygonal; theca 0.2 mm. thick; base deeply covered and basals not seen; stem column round and attached to base in single known specimen.

Deltoids 5.0 mm. long and 6.5 mm. wide at radial deltoid suture; each deltoid ornamented by 13 slightly tuberculated chevrons; 132 degree angle formed by radial deltoid suture; five furrows, 1.0 mm. wide and 1.5 mm. long lead into the five spiracles at the apices of the deltoids.

Radials 8.0 mm. high and 6.4 mm. wide at radial deltoid suture, 2.3 mm. wide at base; radials ornamented by 11 dalaths, none tuberculated.

Ambulacra extend full length of calyx and appear petaloid in outline when viewed ventrally; hydrospire pores extend full length of ambulacra;



Text-fig. 1.—Hydrospire folds of Coral Ridge fauna blastoids. A, *Orbitremites coralridgensis*, n. sp., holotype, U. S. N. M., No. 127324, X 11. B, *Orbitremites kentuckyensis*, n. sp., paratype, U. S. N. M., No. 127318, X 16. C, *Orbitremites kentuckyensis*, paratype, U. S. N. M., No. 127321, X 10. D. *Orbitremites oppelti* Rowley, emend., hypotype, U. S. N. M., No. 127323, X 11. E, *Orbitremites kentuckyensis*, paratype, U. S. N. M., No. 127320, X 15.

width of ambulacrum at radial deltoid suture 1.8 mm.; side plates present, 15 in 5 mm.; hydrospire folds are present, two under each ambulacrum (Text-fig. 1-A) hydrospire folds stalklike and slightly sigmoidal in horizontal section; hydrospire sacs oval to subcircular.

For a detailed analysis of the species, see Table 3.

Remarks.—This species differs from its closest ally, *Orbitremites kentuckyensis* in having a melon (prolate) shape, petaloid appearance of the ambulacra as viewed ventrally, and deep depression of the apices of the deltoids below the surface of the calyx. This species differs from all other species of *Orbitremites* in possessing petaloid shaped ambulacra and a prolate calyx.

The hydrospire folds of *Orbitremites coralridgensis* are similar to those of *O. oppelti* Rowley (compare Text-figs. 1-A and 1-D).

Deposition of type.—The holotype, the only specimen, U. S. N. M., No. 127324, is deposited in the U. S. National Museum, Washington, D. C.

Occurrence.—This species was derived from the Coral Ridge fauna of the upper part of the Coral Ridge member of the New Providence formation in the east quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky.

Orbitremites oppelti Rowley, emend. Conkin Pl. 14, figs. 1-7; Text-fig. 1-D

Description.—Calyx subglobose; height, 24.0 mm.; width, 25.0 mm. at radial deltoid suture; cross section circular above radial deltoid suture; below radial deltoid suture cross section is polygonal.

Deltoids 13.7 mm. long; ornamented with 18 chevrons of varying strength which bear moderately strongly developed tubercles; depressed band at radial deltoid suture formed by bundle of three to possibly four thin dalaths fused with the distal large chevron; the number of dalaths and chevrons fused to form the depressed band seems to vary at each radial deltoid suture.

Radials 16.9 mm. long, ornamented with 12 dalaths; edges of radials and deltoids along ambulacrum are tuberculated throughout their length; first two dalaths below radial deltoid suture are small and smooth; third dalath slightly tuberculated; next three dalaths tuberculated and subequal in size; seventh dalath is of large size, 3.0 mm., with three rows of tubercles; last five dalaths alternate in size; width of radials varies from 13.2

mm. at radial deltoid suture, to 4.0 mm. at base of calyx; radials incurved to help form basal concavity.

Ambulacra 2.4 mm. wide at radial deltoid suture and 1.0 mm. wide at base of calyx; side plates number 14 in 5 mm. of ambulacral length; hydrospire pores extend full length of ambulacrum.

There are two hydrospire folds under each ambulacrum; in section, hydrospire stalks curve gradually and moderately away from axis of ambulacrum, but otherwise are nearly straight and parallel to axis of ambulacrum; hydrospire sacs oval to pyriform.

For a detailed analysis of the hypotypes (U. S. N. M., Nos. 127323 and 127322) see Table 3.

Remarks.—Description of *O. oppelti* is emended on basis of the hypotype (U. S. N. M., No. 127323) which is the best preserved specimen of the species. Rowley (Green, 1902, pp. 86, 87) described *O. oppelti* from three fragments of one individual found in the lower Knobstone shale at a locality two miles north of New Albany, Indiana. The specimens here discussed are the second and third known.

The hypotype (U. S. N. M., No. 127323) varies from the type of *Orbitremites oppelti* only in having a deeper basal concavity, less lobed shape of the calyx, and more sunken ambulacra. Only slight differences in ornamentation can be noted. The hydrospire folds of *O. oppelti* (hypotype, U. S. N. M., No. 127323) are figured and described for the first time (Text-fig. 1-D). Although there are the aforementioned differences, the writer refers the hypotype (U. S. N. M., No. 127323) to *O. oppelti;* the hypotype (U. S. N. M. No. 127322) is somewhat doubtfully compared to *O. oppelti.*

Orbitremites oppelti has affinities to *O. granulatus* (Roemer) and to *O. grandis* Rowley, but it is closest in its affinities to *O. kentuckyensis. O. oppelti* differs from all other species of *Orbitremites* in the possession of a depressed band (daliths and chevrons in a bundle) at the radial deltoid suture. The hydrospire folds resemble those of *O. coralridgensis* in shape.

Deposition of types.—The hypotypes (U. S. N. M., Nos. 127323 and 127322) are deposited in the U. S. National Museum, Washington, D. C.

Occurrence.—Both specimens are from the Coral Ridge fauna of the upper part of the Coral Ridge member of the New Providence formation in the east quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky.

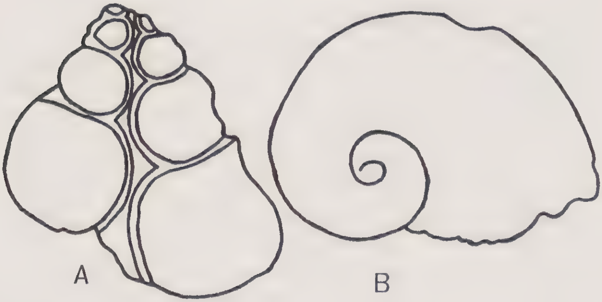
GASTROPODS

Genus **BEMBEXIA** Oehlert, 1888

Bembexia ellenae Conkin, n. sp. Pl. 15, figs. 1-14; Text-fig. 2-A

Description.—Moderate to large, rounded, dextral shell consisting of probably eight whorls; first 1-1½ whorls are never preserved; aperture subcircular to subquadrangular and possesses an outer lip with a deep sinus which generates a selenizone on periphery of shell; upper surface of whorl slightly convex and slopes toward upper carina bordering concave selenizone; selenizone is also limited by a carina at lower edge; selenizone wide, with growth lines curved apically; areas on each side of selenizone slightly concave, subequal in width to selenizone, and ornamented only by fine growth lines curving apically; whorl suture moderately deep; nucleus not observed but presumedly smooth since the initial part of the third whorl and terminal part of second whorl lack sculpture; columella straight; lip reflected over the rimate umbilicus in better preserved specimens, but in other specimens is missing so that narrow umbilicus (less than 1 mm.) may be seen; inductura not observed.

See Table 4 for measurements of *Bembexia ellenae*.



Text-fig. 2.—Sections of gastropods from Coral Ridge fauna, X 7. A, *Bembexia ellenae*, n. sp., paratype, U. S. N. M. No. 127328. B, *Sinuitina anneae*, n. sp., paratype, U. S. N. M., No. 127315.

The number of revolving lines on each whorl is difficult to express by a written description, and most writers have made little attempt to do so. The number of revolving lines on the whorls above the periphery varies due to the intercalation of revolving lines. No attempt is made to make a detailed analysis of the revolving lines on the bases of all the whorls of the shell of *Bembexia ellenae*; only the revolving lines on the bases of the seventh and eighth whorls are given.

The body whorl, the eighth, has a rounded base with 16 to 18 strong revolving lines, each bearing a single row of nodes; fine transverse growth lines occur on the base, and descend into the umbilicus after crossing the lower carina of the selenizone; these lines at first describe an arc aperturally, then gradually bend apically and plunge into the umbilicus.

The base of the seventh whorl is rounded and has slightly more than 14 revolving lines.

Above the selenizone, the eighth whorl possesses five to seven revolving lines; the faint seventh revolving line originates at a point about 1 mm. from the aperture.

Above the selenizone, the seventh whorl has three revolving lines at the initial portion with a set of strong nodes on each revolving line, and five revolving lines at the terminal portion; two of the revolving lines had been intercalated. between the initial portion and the terminal portion of the seventh whorl.

Above the selenizone, the sixth whorl has two revolving lines at its initial portion and at its terminal portion three revolving lines.

Above the selenizone, the fifth whorl has two revolving lines at both its initial portion and its terminal portion. Two rows of nodes on the fifth whorl enlarge and lengthen and curve obliquely apically. Near the aperture of the fourth whorl the two rows of nodes begin to coalesce to form an elongate ridge, but the two rows are still distinct.

At the initial end of the fourth whorl coalescence of the aforementioned nodes forms one evenly rounded, oblique ridge directed apically. Near the aperture of the third whorl the oblique ridge becomes faint and no sculpture is noted on the rest of the third whorl, or on what is preserved of the second whorl. The first 1-1½ whorls are not preserved. Carrying the pattern exhibited on the whorls to its conclusion, the oblique ridge near the aperture of the third whorl probably disappears at about the aperture of the third whorl.

Table 4.—Measurements of types of *Bembexia ellenae*, n. sp. in millimeters

Specimen	Height	Width	Aperture	
			Height	Width
Holotype, No. 127325	16.4	15.4	7.5	9.2
Figured paratype, No. 127326	16.3	15.3	7.8	10.7
Figured paratype, No. 127327	16.0	15.9	7.4	8.2
Unfigured paratypes, No. 127329	21.9	18.6	11.1	10.9
	18.4	17.9	7.8	10.2
	18.0	14.7	10.5	9.1
	18.8	17.2	9.2	9.3
	12.5	11.2	7.1	6.5
	9.0	8.0	5.0	4.7
	6.8	6.5	3.2	3.6

The second whorl, when preserved, is unsculptured.

Remarks.—*Bembexia ellenae* is closely related to *B. stellaeformis* (Hyde), (Marple, 1953, pp. 325, 326, pl. 46, figs. 1-4). Hyde described a new species of gastropod from the Logan formation of Ohio under the name *Mourlonia? stellaeformis.* The author has examined the types of this species and has concluded that this form is a species of *Bembexia.* Hyde's description is adequate so that no further description of *Bembexia stellaeformis* is given here.

Bembexia ellenae is closely related to *B. stellaeformis* in its overall shape and in the kind of ornamentation. There are, however, several distinct differences that set the two species apart specifically as is shown in the following comparison.

Bembexia ellenae	*Bembexia stellaeformis*
1. Mature shell presumedly of eight whorls	1. Mature shell of 5 to 6 whorls
2. No definite flattened area on periphery	2. Definite flattened area on periphery
3. Slightly convex above periphery	3. Flattened above periphery
4. Sutures distinct	4. Sutures indistinct
5. Umbilicus minutely phaneromphalus	5. Umbilicus open
6. Five to 7 revolving lines above the presumed 8th whorl; 3 distinct revolving lines above periphery on 6th whorl	6. Above periphery, one distinct and one to two indistinct revolving lines on 6th whorl
7. Figured types average 15.4 mm. in height	7. Shells average 8 to 9 mm. in height
8. Sixteen to 18 revolving lines on base of 8th whorl	8. Eight to 10 revolving lines on base

This new species of *Bembexia* is named for the writer's wife, Barbara Ellen, in recognition of her valued help in completing the manuscript for publication.

Deposition of types.—The holotype, U. S. N. M., No. 127325; figured paratypes, U. S. N. M., Nos. 127326 and 127327; seven unfigured paratypes, U. S. N. M., No. 127329; and one sectioned figured paratype,

U. S. N. M., No. 127328, are deposited in the U. S. National Museum, Washington, D. C.

In addition, six unfigured paratypes are deposited in each of the following institutions in the United States.

Department of Geology:

- American Museum of Natural History, New York, No. 27954.
- Univ. of Cincinnati, Cincinnati, Ohio, No. 34421.
- Univ. of Colorado, Boulder, Colo., No. 975.
- Univ. of Indiana, Bloomington, Ind., No. 5556.
- Univ. of Iowa, Iowa City, Ia., No. 2322.
- Univ. of Kentucky, Lexington, Ky., No. 14255.
- Univ. of Missouri, Columbia, Mo., No. 12864.
- Univ. of Oklahoma, Norman, Okla., No. 445.

Museum of Paleontology, Univ. of Michigan, Ann Arbor, Mich., No. 33460.

Paleontological Research Institution, Ithaca, New York, No. 1832, three unfigured paratypes.

Six unfigured paratypes are also deposited in each of the following institutions in other countries.

Dept. of Geology, British Museum (N. H.), London, England, Nos. PG-2561-2566.

Institut und Museum für Geologie und Paläontologie der Universität Tübingen, Tübingen, Germany, No. GA 1087/1.

Zaklad Paleozoologii, University of Warsaw, Warsaw, Poland, No. G 101.

Occurrence.—The holotype, figured paratypes, and unfigured paratypes deposited in the U. S. National Museum are all from the Coral Ridge fauna of the upper part of the Coral Ridge member of the New Providence formation in the east quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky. This species also occurs in numbers in the Coral Ridge fauna at Kenwood Hill, Jefferson County, Kentucky.

In addition, a few casts of large gastropods (with all ornamentation absent) which are probably *Bembexia ellenae*, or a new and related species, have been noted in the Button Mold Knob fauna at Jacobs Hill and Findley Knob, Jefferson County, Kentucky.

Genus **SINUITINA** Knight, 1945

Sinuitina anneae Conkin, n. sp. Pl. 16, figs. 1-13; Text-fig. 2-B

Description.—Planispiral shell, consisting of two and one half whorls, nearly involute; shell cross section subcardiform, with an open umbilicus; dorsum only faintly trilobed even in old individuals; growth lines in form of coarse lirae develop a deep median sinus on dorsum, but no selenizone is present; lateral face of shell convex; umbilical slope divided into two parts by circum-umbilical carina: 1) upper convex slope, and slope concavity forming a furrow bordered by the circum-umbilical carina at edge of umbilicus, and 2) below circum-umbilical carina, whorl base becomes parallel to nearly vertical umbilical opening and overlaps three-fourths of preceding whorl.

From circum-umbilical carina, moderately coarse growth lirae are developed which bend apically all along furrow and upper concave slope; at top of umbilical slope, intercalation of lirae occurs and lirae bend aperturally until at midpoint of lateral face they turn abruptly apically forming 120 degree angle, and then continue until reaching the moderately acute dorsum where lirae of both lateral faces join and describe a 60 degree angle; each lira produces an ornamental pattern resembling a chevron on each lateral face of the shell and on the dorsum.

In addition to moderately coarse growth lirae, sets of minute chevron-shaped lirae (about 160 per 5 mm.) occur in bundles between the coarser growth lirae. The chevron bundles tend to line up aperturally apically to give the appearance of interrupted revolving line sculpture with the points of the chevrons directed aperturally. These small chevron bundles are somewhat more raised in the center than on the flanks and where they touch the coarser lirae they produce a beaded pattern. The chevron-shaped bundles cover the entire shell surface although in the present material weathering has stripped most specimens of their ornamentation.

See Table 5 for measurements of *Sinuitina anneae.*

Remarks.—*Sinuitina anneae* is most closely related to a form which was identified as *Tropidodiscus cyrtolites* Hall by Hyde (Marple, 1953, pp. 319, 320, pl. 46, fig. 32). However, this species of Hyde's is a species of *Sinuitina.* Whether a new specific name for Hyde's form will be necessary must await a study of the original material of Hall, if it is now available.

The differences between *Sinuitina anneae* and *Tropidodiscus cyrtolites* as described and figured by Hyde, are given below.

Sinuitina anneae	*Tropidodiscus cyrtolites* of Hyde
1. Angle at middle of lateral face is smaller, about 120 degrees, and is chevron-shaped.	1. Angle at middle of lateral face is larger, about 160-170 degrees, and is broadly loop-shaped.
2. Angle on dorsum more acute, about 60 degrees.	2. Angle on dorsum not so acute, about 80-85 degrees.
3. More coarse transverse lirae per unit area.	3. Less coarse transverse lirae per unit area.
4. Intercalation of transverse lirae dorsad to middle of lateral face of whorl and also at top of umbilical slope.	4. Intercalation at top of umbilical slope.

Table 5.—Measurements of *Sinuitina anneae*, n. sp., in millimeters

Specimen and U. S. N. M. No.	Diameter of umbilicus, from one circum-umb. ridge to other.	Length	Aperture (none complete)		Number of coarse lirae in middle of lateral face.
			Height	Width	
Holotype 127310	0.92	7.8	4.8	4.9	6-8
Paratype 127311	1.39	11.9	8.3	6.6	4-6
Paratype 127312	1.68	13.1	7.7	7.5	4-6
Paratype 127313	2.00	13.8	8.0	8.7	4-6
Paratype 127314	about 2.0 to 3.0, obscured	23.1	14.0	14.1	2½-3

Sinuitina anneae is also closely related to the type species, *S. cordiformis* (Newell) (1935, pp. 349, 350) from the Lansing beds (Upper Pennsylvanian) of Oklahoma. The differences between *S. anneae* and *S. cordiformis* are given below.

Sinuitina anneae	*Sinuitina cordiformis*
1. On small specimens the peripheral ridge is not easily seen and is seen only moderately well when specimen has width of 10 mm. and length of 15 mm.	1. Peripheral ridge well developed in small individuals.
2. Angle formed by the coarse transverse growth lines at the middle of the lateral face is acute.	2. This corresponding angle is obtuse.
3. Coarse growth lines form a discrete and acute angle over the dorsum.	3. There is a less discrete and not so acute angle formed over the dorsum.
4. Greater number of transverse lirae per unit area.	4. Lesser number of transverse lirae per unit area.
5. Intercalation of coarse transverse lirae occurs at the middle of lateral face of whorl and also at top of umbilical slope.	5. Intercalation of coarse transverse lirae at umbilical shoulder.
6. Whorl surface ornamented by minute chevron bundles as well as by transverse lines.	6. This delicate ornamentation cannot be seen in figures of *Sinuitina cordiformis.*
7. Larger size of shell.	7. Smaller size of shell.

Newell (1935) made no mention of the intercalation of coarse lirae at the middle of the lateral face nor of the presence of chevron-shaped bundles in *Sinuitina cordiformis.* The size of the shell is not regarded as a specific character in the present discussed species of *Sinuitina.*

This new species of *Sinuitina* is named for the author's younger daughter Anne.

Deposition of types.—The holotype, U. S. N. M., No. 127310, five figured paratypes, U. S. N. M., Nos. 127311-127314, and one sectioned figured paratype, U. S. N. M., No. 127315, are deposited in the U. S. National Museum, Washington, D. C.

In addition, two unfigured paratypes are deposited in each of the following institutions in the U. S. A.

Department of Geology:

American Museum of Nat. History, New York, No. 27955.
Univ. of Cincinnati, Cincinnati, Ohio, No. 34422.
Univ. of Colorado, Boulder, Colo., No. 976.
Univ. of Indiana, Bloomington, Indiana, No. 5557.
Univ. of Iowa, Iowa City, Iowa, No. 2321.
Univ. of Kentucky, Lexington, Ky., No. 14356.
Univ. of Missouri, Columbia, Mo., No. 12865.
Univ. of Oklahoma, Norman, Okla., No. 446.

Museum of Paleontology, Univ. of Michigan, Ann Arbor, Mich., No. 33461.

Paleontological Research Institution, Ithaca, New York, No. 1831, two unfigured paratypes.

Also, two unfigured paratypes are deposited in each of the following institutions in other countries.

Dept. of Geology, British Museum (N. H.), London, England, Nos. PG-2567-2568.

Institut und Museum für Geologie und Paläontologie der Universität Tübingen, Tübingen, Germany, No. GA 1087/2.

Zaklad Paleozoologii, University of Warsaw, Warsaw, Poland, No. G 101.

Occurrence.—The holotype and figured paratypes are from the Coral Ridge fauna of the upper part of the Coral Ridge member of the New Providence formation in the east quarry of the Coral Ridge Brick and Tile Company, Coral Ridge, Jefferson County, Kentucky. This species also occurs in some numbers in the Coral Ridge fauna at Kenwood Hill, Jefferson County, Kentucky. The unfigured paratypes are from both Coral Ridge and Kenwood Hill.

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ADDENDUM

Since submitting the manuscript for publication, the writer has discovered the first occurrence of the Coral Ridge fauna in Indiana. The Coral Ridge fauna was found in the Louisville Cement Company quarry on State Highway 60, 2.6 miles northwest of the intersection of Highway 60 and U. S. Highway 31W, or about 8 miles north of New Albany, in Clark County, Indiana. This finding considerably increases the known geographic distribution of the Coral Ridge fauna.

The lithologic character of the lower and upper parts of the Coral Ridge member is the same as at the type locality, the east quarry of the Coral Ridge Brick and Tile Corp., Coral Ridge, Jefferson County, Kentucky.

The upper part of the Coral Ridge member carries the Coral Ridge fauna. Only *Bembexia ellenae,* n. sp., *Sinuitina anneae,* n. sp., *Amplexus,* and coprolites were noted.

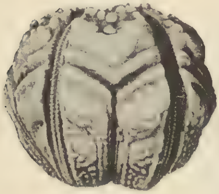
PLATES

EXPLANATION OF PLATE 13

All figures approximately × 2 except where noted

Figure		Page
1-20.	**Orbitremites kentuckyensis,** n. sp.	135

1-4. Interambulacral, ambulacral, ventral, and basal views of holotype, U. S. N. M., No. 127316. 5-8. Interambulacral, ambulacral, ventral, and basal views of paratype, U. S. N. M., No. 127318. 9-12. Interambulacral, ambulacral, ventral, and basal views of paratype, U. S. N. M., No. 127319. 13-16. Interambulacral, ambulacral, ventral, and basal views of paratype, U. S. N. M., No. 127317. 17-20. Interambulacral, ventral, and basal views, and sectional view (× 14) showing two hydrospire folds under one ambulacrum, of paratype, U. S. N. M., No. 127320.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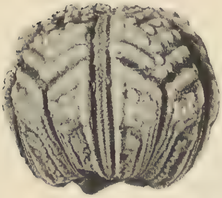
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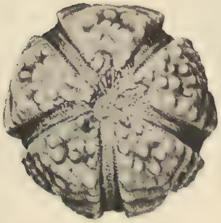
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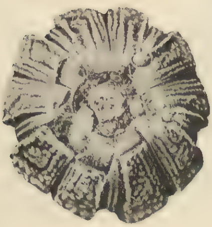
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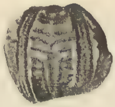
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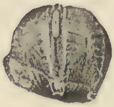
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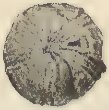
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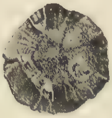
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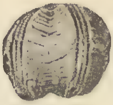
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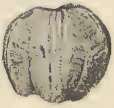
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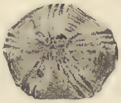
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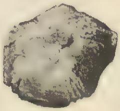
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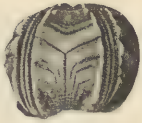
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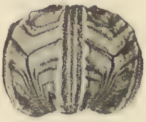
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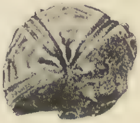
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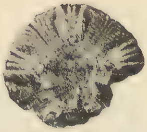
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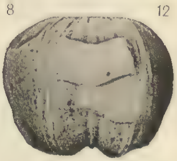
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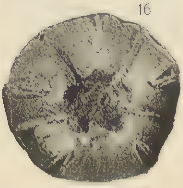
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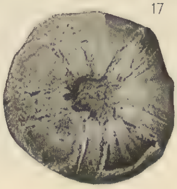
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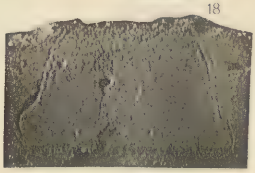
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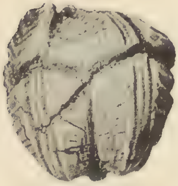

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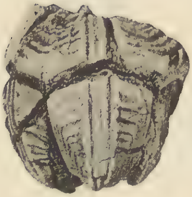

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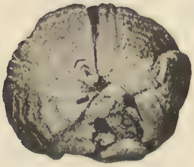

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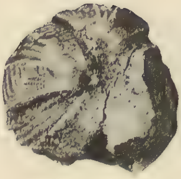

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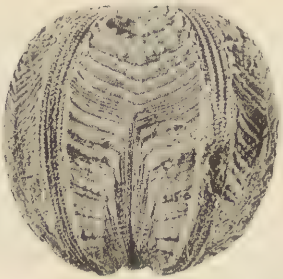

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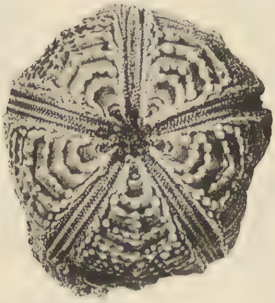

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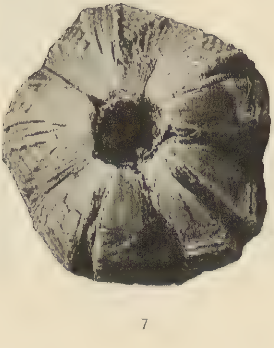

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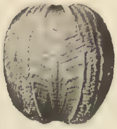

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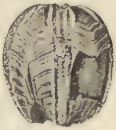

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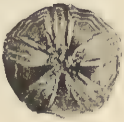

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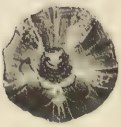

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EXPLANATION OF PLATE 14

All figures approximately × 2

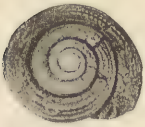
Figure		Page
1-4.	**Orbitremites** cf. **O. oppelti** Rowley	139
	Interambulacral, ambulacral, ventral, and basal views of hypotype, U. S. N. M., No. 127322.	
5-7.	**Orbitremites oppelti** Rowley, emend.	139
	Interambulacral, ventral, and basal views of hypotype, U. S. N. M., No. 127323.	
8-11.	**Orbitremites coralridgensis,** n. sp.	137
	Interambulacral, ambulacral, ventral, and basal views of holotype, U. S. N. M., No. 127324.	

EXPLANATION OF PLATE 15

All figures approximately × 2

Figure		Page
1-14.	**Bembexia ellenae,** n. sp.	141

1-4. Top, apertural, side, and basal views of paratype, U. S. N. M., No. 127327. 5-8. Top, apertural, side, and basal views of paratype, U. S. N. M., No. 127326. 9-12. Top, apertural, side, and basal views of holotype, U. S. N. M., No. 127325. 13. Siliceous geode with a pyritized specimen of *Bembexia ellenae.* 14. Large ironstone nodule with three ironstone specimens of *Bembexia ellenae.*



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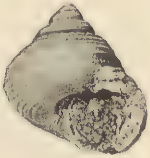

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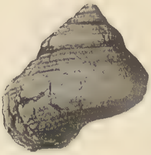

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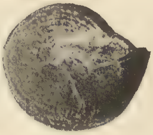

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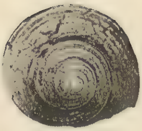

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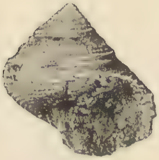

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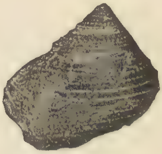

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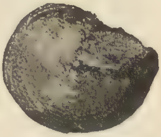

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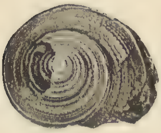

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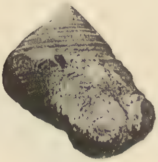

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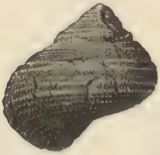

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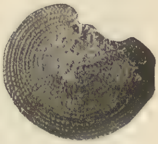

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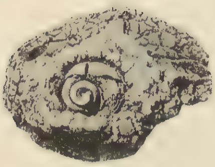

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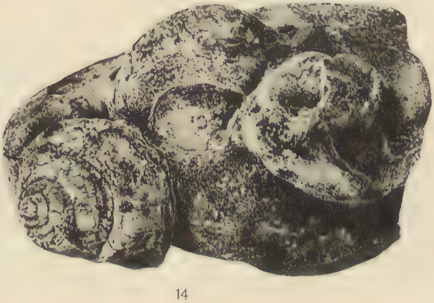

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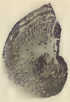
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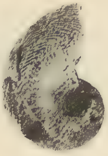
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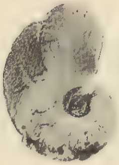
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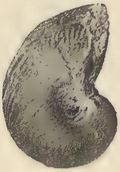
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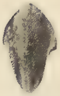
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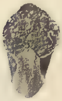
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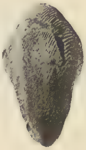
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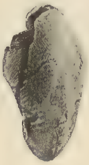
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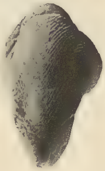
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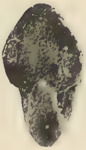
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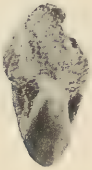
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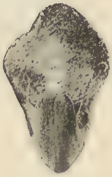
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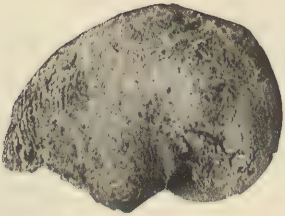
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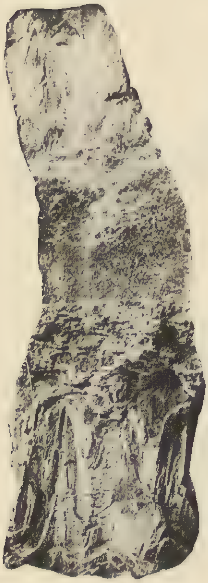
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Explanation of Plate 16

All figures approximately × 2.5 except where noted

Figure Page

1-13. **Sinuitina anneae,** n. sp. 146

1-3. Side, dorsal, and apertural views of holotype, U. S. N. M., No. 127310. 4-6. Side, dorsal, and apertural views of paratype, U. S. N. M., No. 127311. 7-9. Side, dorsal, and apertural views of paratype, U. S. N. M., No. 127312. 10-12. Side, dorsal, and apertural views of paratype, U. S. N. M., No. 127313. 13. Side view of largest specimen, paratype, U. S. N. M., No. 127314.

14. Cone-in-cone 124

Small piece of ironstone double cone-in-cone lens with undisturbed layer between cone-in-cone layers × 1.7.

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SPRINGVALEIA, A LATE MIOCENE XENOPHORA-LIKE TURRITELLID FROM TRINIDAD

By

W. P. Woodring
U. S. Geological Survey, Washington, D. C.

January 30, 1958

Paleontological Research Institution
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SPRINGVALEIA, A LATE MIOCENE XENOPHORA-LIKE TURRITELLID FROM TRINIDAD*

W. P. Woodring
U. S. Geological Survey

ABSTRACT

Springvaleia is a remarkable turritellid characterized by a *Xenophora*-like agglutinated facade—the only slender gastropod having such architecture. It is found on the north slope of the Central Range of Trinidad in the upper part of the upper Miocene Springvale formation; in the glauconite sandstone exposed at Springvale quarry, in the same sandstone at localities between Springvale quarry and Savaneta River, and in the Melajo clay member of the Springvale formation at the foot of the Northern Range.

Some Devonian euomphalid gastropods (*Philoxene*) have a sparse sprinkling of agglutinated objects. A Miocene Mexican modulid (*Psammodulus*) and a Recent diastomid (?) (*Scaliola*) are selective in using only sand grains. *Xenophora* and *Springvaleia* have a dense assortment of coarse agglutinated objects. The polytypic *Xenophora* has been widely distributed since Late Cretaceous time, whereas the monotypic *Springvaleia* survived only during part of late Miocene time and had a restricted distribution.

INTRODUCTION

In 1867 R. J. Lechmere Guppy (1867, p. 168), Chief Inspector of Schools in Trinidad and pioneer paleontologist of that island, described as *Scalaria leroyi* a Miocene gastropod found in the "Caroni beds at Savonetta". The description is brief and is not accompanied by an illustration. Guppy (1873, p. 75, pl. 1, fig. 10) redescribed and illustrated the species a few years later. That description and illustration, however, represent an irrelevant digression, for they were based on an epitonid from the late middle Miocene Bowden formation of Jamaica. There is no reason to suppose that the species from Trinidad and the Jamaican species have anything to do with each other. Therefore, Maury (1925, p. 242) renamed the Jamaican species *Epitonium* (*Acrilla*) *pseudoleroyi.* It was later (Woodring, 1928, p. 402, pl. 32, figs. 3, 4) described and illustrated as *Ferminoscala pseudoleroyi*, but the generic name *Ferminoscala* since then has been supplanted by the earlier name *Scalina* (Palmer, 1937, p. 102). Guppy's description and illustration of 1873 were repeated in a paper he published in 1874 (Guppy, 1874, p. 406, pl. 16, fig. 10). The 1874 paper, however, also included a plate of Trinidad fossils, and a specimen of *Scalaria leroyi* from Trinidad was illustrated (pl. 18, fig. 2). Maury (1925, p. 241) thought that specimen should be rejected as *Scalaria leroyi* but gave no reasons for her decision. In the absence of evidence to the contrary, the illustration is to be accepted as an illustration of *Scalaria leroyi.* In 1910 Guppy (1910, p. 451, 453) recorded *Scalaria leroyi* from the same formation in Trinidad—now known as the Springvale formation—as his original lot and from the same fossiliferous sandstone in the formation, but from a different locality: Springvale [Springvale quarry]. He added nothing further than the remark that "the surface characters of the shells are so much destroyed by fossilization that a doubt rests on the correctness of the determination".

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*Publication authorized by the Director, U. S. Geological Survey.

The current concept of *Scalaria leroyi* is based on Maury's interpretation (1925, p. 241, pl. 41, figs. 8, 11) 58 years after Guppy proposed his name. Her identification was based on 20 specimens from Springvale [Springvale quarry]: preserved shells, not molds as she described them. Though her fossils are not well preserved, she had no difficulty in recognizing that the shells are pitted and faceted by agglutinated foreign objects —a remarkable feature for a many-whorled slender shell. Maury realized that her shells have no epitonid affinities but did not know what their affinities are and so let the species go as *Epitonium ? leroyi.* Her intention would have been expressed better by *"Scalaria" leroyi* or *"Epitonium" leroyi.* My suggestion (Woodring, 1928, p. 403)—made before specimens were examined—that Maury's fossils may be *Opalia*-like was ill-founded. Vokes (1938, p. 5) listed *Epitonium ? leroyi* from Springvale [Springvale quarry] without comment. Finally Rutsch (1942, p. 133) proposed the generic name *Springvaleia* for *Scalaria leroyi* as identified by Maury and illustrated a shell from a locality close to, if not at, the type locality: the first illustrations clearly showing the unusual features.

Guppy's description, remarks, and illustration reveal inconsistencies and suggest that he not only was dealing with poorly preserved material, but also that he may have included fossils of different affinities under *Scalaria leroyi.* His original description of "longitudinal ribs few, indistinct" does not agree with the 1873 and 1874 remark that "my original description of this shell was drawn up from an examination of the specimens found in Trinidad which are so much altered by fossilization that the character of the surface is not determinable" or with the 1874 illustration. Not much can be made out of the illustration. It suggests a mold of a small, slender, many-whorled gastropod with a restored unconvincing aperture. Moreover, the original account included the statement that "the example figured [the original account has no illustration] is a small one, but like nearly all the Mollusca of the Caroni series in Trinidad, the shell appears to have grown to a very large size, for another specimen in my cabinet is upwards of 6 inches long". That dimension is improbable for Maury's *Epitonium ? leroyi* and perhaps may be equally improbable for Guppy's *Scalaria leroyi.*

The small specimen mentioned in the original account as the one illustrated is presumed to be the specimen illustrated in 1874. It, therefore, evidently was selected from the type lot and may be considered the type, or at least would be chosen as the lectotype, if it were available and recognizable, even though the illustration does not agree with the description. The type lot, however, was destroyed. In 1893 W. H. Dall purchased, for the U. S. National Museum, Guppy's collection of Caribbean Tertiary fossils. No specimens of *Scalaria leroyi* from Trinidad were forwarded, although the Jamaican specimen Guppy described and illustrated as that species (the type of *Scalina pseudoleroyi*) was included in the shipment. The type lot of *Scalaria leroyi* presumably was in the Guppy collection at the Royal Victoria Institute Museum at Port-of-Spain. Mr. J. A. Bullbrook, Curator of that institution, informed me that the original Museum and its contents were destroyed by fire in 1920.

In the absence of primary type material Guppy's species is unrecognizable. It would have been better had Maury considered his name a *nomen dubium*, which it is, and had described her specimens as a new species. Rutsch accepted Maury's identification, although he realized Guppy's species is unrecognizable. The same course is adopted in the present paper but is adopted under protest. Nevertheless renaming of Maury's species is to be avoided as long as there is a remote possibility that her identification is correct, even though the possibility cannot be proven or disproven. Guppy's description of "longitudinal ribs, few, indistinct" may be a description of the irregular faceting produced by impressions of agglutinated objects. If Maury's identification is accepted, a name-bearer is needed. Rutsch designated one of Maury's figured specimens as the neotype. It is improbable, however, that her specimens were collected at the type locality. Guppy's original locality, the type locality, is "Savonetta", which is presumed to mean a locality near Savaneta River. He did not publish the occurrence of the species at Springvale quarry until 43 years later and then cast doubt on his identification. A neotype from a locality near Savaneta River is designated in the present paper.

I am indebted to Dr. H. G. Kugler, of the Trinidad Oil company, Ltd. (formerly Trinidad Leaseholds, Ltd.), for stratigraphic and locality data and for collections of Springvale fossils, and to Mr. R. I. Levorson, of

Dominion Oil, Ltd., for the collection of fossils containing the well-preserved specimen herewith illustrated. Dr. K. V. W. Palmer, Director of the Paleontological Research Institution, kindly loaned Maury's specimens. The drawings were prepared by Mrs. Elinor Stromberg and the photographs by N. W. Shupe.

DESCRIPTION OF SPRINGVALEIA LEROYI

Family **TURRITELLIDAE**

Genus **SPRINGVALEIA** Rutsch, 1942

Rutsch, 1942, Naturforsch. Gesell. Basel, Verh., Bd. 54, p. 133.

Type (*orthotype* [1]).—*Scalaria leroyi* Guppy, Miocene, Trinidad.

Springvaleia leroyi (Guppy) Pl. 17, figs. 1-5

Scalaria leroyi Guppy, 1867, Sci. Assoc. Trinidad, Proc., v. 1, p. 168, (reprinted, Bull. Am. Paleont., v. 8, No. 35, p. 47, 1921); Guppy, 1873, Sci. Assoc. Trinidad, Proc., v. 2, p. 75, (comments on specimens from Trinidad only, not description or pl. 1, fig. 10) (reprinted, without illus., Bull. Am. Paleont., v. 8, No. 35, p. 59, 1921); Guppy, 1874, Geol. Mag., dec. 2, v. 1, p. 406, pl. 18, fig. 2, (comments on specimens from Trinidad, not description or pl. 16, fig. 10); Guppy, 1910, Agri. Soc. Trinidad and Tobago, Proc., v. 10, p. 451, 453, (reprinted, Bull. Am. Paleont., v. 8, No. 35, p. 148, 150, 1921).

Epitonium? leroyi (Guppy), Maury, 1925, Bull. Am. Paleont., v. 10, No. 42, p. 241, pl. 41, figs. 8, 11; Vokes, 1938, Am. Mus. Novitates, No. 988, p. 5.

Springvaleia leroyi (Guppy), Rutsch, 1942, Naturforsch. Gesell. Basel, Verh., Bd. 54, p. 133, pl. 7, figs. 1a, 1b.

Of medium size to moderately large (50 mm. to estimated 80 mm.), moderately thin-shelled to thick-shelled, turritelloid, apical angle narrow, all except earliest whorls strongly inflated. Protoconch apparently consisting of about 1½ moderately inflated whorls, earliest half whorl not preserved. Early post-protoconch whorls relatively high and narrow, first two moderately inflated. Sculpture not apparent on earliest post-protoconch whorls (all of which are somewhat worn), except a few indistinct narrow spiral threads on anterior part of first. All post-protoconch whorls bearing agglutinated bits of rock, shells, Bryozoa, and barnacles, all small and flat or almost flat, or showing pits of varying depth marking sites of agglutinated objects dislodged before fossilization. Sculpture between agglutinated objects and pits consisting of closely spaced microscopic spiral threads of two ranks, frosted by still finer axial threads. Aperture turritelloid, but lips not preserved. Growth line not clear owing to gaps, but sinus apparently wide, shallow and located about at middle of whorl. Growth-line angle (angle between axis of shell and line extending from posterior end of growth line to anterior end) apparently moderately wide. Base sculptured with closely spaced microscopic spiral threads of two poorly defined ranks.

---

[1] An orthotype is an originally designated type species.

Dimensions.—Height (incomplete), 51.8 mm.; diameter (including agglutinated flat objects), 10 mm. (larger figured specimen).

Type.—Primary type material destroyed. Neotype (herewith designated): specimen illustrated by Rutsch, Naturhist. Mus. Basel 471/190.

Type locality.—"Savonetta" Trinidad (evidently a locality near Savaneta River, Montserrat Ward, Caroni County, on outcrop of fossiliferous sandstone exposed at Springvale quarry). Locality of neotype: Trinidad Leaseholds, Ltd., locality R. R. 124, Rutsch's Brechin Castle Estate locality, 450 feet south of Savaneta River (Couva River of Rutsch, 1942, text fig. 1) and 125 feet south of Couva Road.

In his 1942 publication Rutsch did not use family headings and did not assign his new genus to a family. The systematic position, however, immediately following *Turritella* indicated that he thought it is allied to that genus. *Springvaleia* is a turritellid—a remarkable turritellid that acquired a *Xenophora*-like facade. It is the only genus of slender gastropods that has an architecture like that of *Xenophora.* The thickness of the shell depends on the depth of the pits where the agglutinated objects were lodged.

Through 30 specimens, showing growth stages from a diameter of .35 mm. to 20 mm. are available, the development of the sculpture is unknown, as the early post-protoconch whorls are worn and pitted. The smallest specimen (height of 5½ whorls, 3.5 mm., diameter, 1.3 mm., U.S.G.S. locality 18255) includes the later part of the protoconch (diameter .35 mm.) and the earliest post-protoconch whorls (diameter of first .5 mm.). Most of the 30 specimens are somewhat worn and show only traces of the narrow spiral threads.

The strongly inflated whorls, narrow spiral threads and the growth line, as far as it can be made out, suggest that *Springvaleia* was derived from a species of *Turritella* similar to *T. gatunensis* Conrad (Woodring, 1957, p. 108, pl. 23, figs. 4, 5, 9, 14), which is widely distributed in the Miocene deposits of the southern part of the Caribbean region from Panamá to Venezuela. The early post-protoconch whorls of *T. gatunensis,* however, bear a strong median spiral, which develops into the posterior primary spiral of later whorls. *T. caronensis* Mansfield (1925, p. 51, pl. 8, figs.

12-14), a middle Miocene species from Trinidad, is a more likely predecessor. Its early sculptured whorls lack the strong median spiral of *T. gatunensis. T. caronensis* was described as a subspecies of *T. gatunensis.* Though it is closely related to *T. gatunensis,* the development of the sculpture is so different that it is given specific rank. The spiral threads of *Springvaleia leroyi* are of two ranks, but the primary and secondary spirals are not so strongly differentiated as those of *T. caronensis* and *T. gatunensis*, and they are narrower. It is unfortunate that the type of *T. caronensis* was selected from a float collection. That species is represented in five collections now in the U. S. National Museum, but all were gathered as float along Caparo River in the outcrop area of the middle Miocene Manzanilla formation. Mansfield thought that his species is the same as Maury's *T. gatunensis* from outcrop localities in the Manzanilla formation (Maury, 1925, p. 229, pl. 42, fig. 12). Maury's specimens, however, are fragments of late whorls, and early whorls are needed to confirm her species as *T. caronensis.* Whether *T. caronensis* is the predecessor of *Springvaleia leroyi* will remain uncertain until the development of the sculpture and the entire growth line of *S. leroyi* are known. The Melajo clay member is the most promising part of the Springvale formation for specimens showing those features.

The Springvale formation (Kugler, 1956, p. 97), which has a maximum thickness of 4,500 feet, overlies the Manzanilla formation. The fossiliferous, glauconitic, clayey sandstone exposed at Springvale quarry (also known as Mt. Pleasant quarry), about a mile northeast of Forres Park, is in the upper part of the formation below the Mamural clay member. Owing to oxidation of the glauconite, outcrops of the sandstone and its fossils have a characteristic ocherous color. Four lots of fossils in the U.S. National Museum, collected at localities in the 4½-mile stretch between Springvale quarry and Savaneta River contain eight specimens of *Springvaleia leroyi* and Maury's collection from Springvale quarry consists of 20 specimens, some of which are fragments of a few whorls or less than a whorl. Several of her fossils (Paleont. Research Inst., No. 4090 lot no.), including those illustrated (Paleont. Research Inst., Nos. 1084, 1087) show the microscopic sculpture and others show the sculpture of the base. Two fragments of less than a whorl (diameter of larger 20 mm.) represent the largest known specimens, indicating an estimated height of about 80 mm., which is far short of the six inches (152 mm.) mentioned by Guppy for his *Scalaria leroyi.*

The best preservation is shown by a specimen from the Melajo clay member of the Springvale formation (Pl. 17, figs. 2-5). Only small patches of sculpture are shown on a smaller specimen in the same collection. The early whorls are not preserved on either. The Melajo clay member (Kugler, 1956, p. 71, 76) is exposed on Melajo River at the foot of the Northern Range of Trinidad, 30 miles northeast of Springvale quarry. The strata, consisting in ascending order of a basal conglomerate, fragmental pebbly limestone and silty clay, rest directly on the low-grade metamorphic rocks of the Northern Range. The clay contains a molluscan fauna of some 120 species. Though many of the species are found in the sandstone exposed at Springvale quarry, the fauna of the Melajo indicates deposition at greater depth.

The Springvale formation contains the largest and most completely described late Miocene molluscan fauna in the Caribbean region. Rutsch (1942, p. 101-104) listed 153 species and subspecies found at Springvale quarry and his Brechin Castle Estate locality. Some 20 additional species, collected at localities in a distance of 10 miles between Springvale quarry and Quebrada Grande, north of Savaneta River, are in collections recently deposited in the U. S. National Museum by H. G. Kugler. Three collections from the Melajo clay add at least 50 other species. Other parts of the Springvale formation are fossiliferous, but *Turritella montserratensis* Mansfield (1925, p. 53, pl. 9, figs. 5, 6; properly *T. altilira montserratensis*), found in glauconitic silty sand about 1,000 feet below the sandstone at Springvale quarry, is the only form so far described.

Material examined: The locality numbers in the following list, other than Paleont. Research Inst. numbers, are U.S.G.S. Cenozoic numbers.

275, 553. Paleont. Research Inst., Springvale [Springvale quarry]. G. D. Harris, 1920 (275); R. A. Liddle, 1920 (553); 20 specimens.

18255. Springvale quarry, abandoned overgrown quarry about a mile northeast of Forres Park, on east side of stream east of road. H. M. Bolli, K. Rohr, and W. P. Woodring, 1951; 3 specimens.

9224. "Springvale, 2 miles(?)" [probably error in locality register; Mansfield (1925, p. 7) cited the locality as the same as that for 9195: near Couva, Mt. Pleasant road, about ¾ to 1 mile south of Milton]. J. A. Bullbrook, 1918; 3 specimens.

20428. Trinidad Oil Company, Ltd., K.9871 (R.R. 124). Savaneta River area, Boutakoff's Brechin Castle Estate locality. Received from H. G. Kugler, 1957; 1 specimen.

20429. Trinidad Oil Company, Ltd., K.9872. Savaneta River area, 1,700 feet southwest of Philippine Estate house and 250 feet northwest of K.9871 (U.S.G.S. 20428). Received from H. G. Kugler, 1957; 1 specimen.

18634. East bank of Melajo River, about 10,000 feet upstream from Toco Main Road, foot of Northern Range, about 5 miles inland from east coast. Received from Dominion Oil Company, Ltd., 1953; 2 specimens.

AGGLUTINATING ARCHITECTURE IN GASTROPODS

Many marine animals build tests or shelters of agglutinated material picked up from the sea floor or construct a facade of such material. Though agglutinating architecture is rare in gastropods, it appeared fairly early in gastropod history. My colleague E. L. Yochelson points out that the Devonian genus *Philoxene* Kayser, 1889, (Knight, 1941, p. 241) was based on agglutinating architecture. According to Knight (1941, p. 242), the type lot of the type species does not show this feature, although it is shown by probably conspecific specimens. *Philoxene* has been treated as a genus or as a subgenus of *Straparollus*. Some species that bear agglutinated objects, however, have the outline of *Euomphalus*. These Paleozoic gastropods have only a sparse sprinkling of agglutinated objects.

Two genera are selective in using only sand grains: the middle Miocene Mexican modulid *Psammodulus* Collins (1934) and the Recent minute diastomid (?) *Scaliola* A. Adams (1868, p. 52-54, pl. 4, fig. 6), found in the western Pacific Ocean.

The well-known *Xenophora* Fischer von Waldheim and *Springvaleia* build a facade of coarse assorted material, principally shells and rocks. A slender high-spired shell like *Springvaleia* would be immobilized if it attempted to use the large objects almost habitually used by *Xenophora*.

Xenophora has been widely distributed in tropical and warm temperate seas since Late Cretaceous time, but *Springvaleia* survived only during part of late Miocene time and had a restricted distribution. *Xenophora* has been "successful", whereas *Springvaleia* was notably "unsuccessful". The middle Miocene mollusks of the Caribbean region are fairly well known, and there are no intermediates between *Turritella* and *Springvaleia*. As far as the record goes, *Springvaleia* arose in a single step. Its gene pool evidently included lethal genes or genes that were genetically lethal through control of fertility. It did not take long for either set to build up into a homozygous condition in the small restricted population.

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PLATE

EXPLANATION OF PLATE 17

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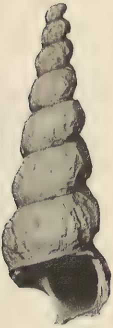
1-5.	**Springvaleia leroyi** (Guppy)	166

1. U. S. G. S. locality 9224, U. S. N. M. 562494; × 4.

2-5. U. S. G. S. locality 18634, U. S. N. M. 562491. 2, × 10; 3-5, × 2.

(Figures 3 and 4 are slightly too large for × 2 and figure 5 is slightly too small.)



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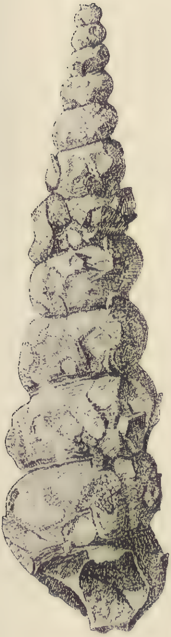

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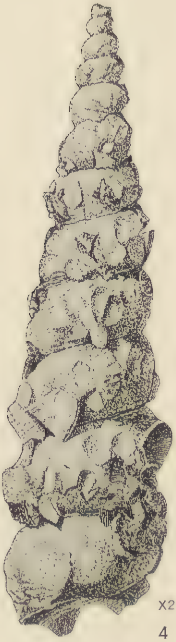

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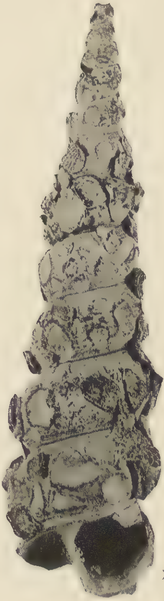

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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA No. 1

By

W. Storrs Cole
Cornell University, Ithaca, New York

March 28, 1958

Paleontological Research Institution
Ithaca, New York, U. S. A.

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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA—No. 1*

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ABSTRACT

The synonyms and variation in the following species are discussed: *Operculinoides floridensis* (Heilprin), *Operculinoides dia* (Cole and Ponton), *O. sabinensis* (Cole), *Amphistegina parvula* (Cushman), *Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall, and *Asterocyclina penonensis* Cole and Gravell. Several middle and upper Eocene species are combined with *O. floridensis* and numerous Oligocene species are referred to *Operculinoides dia* (Cole and Ponton). The suggestion is made that minor differences between individuals living in different environments are caused by environmental factors, thus producing ecological variants of a species to which individual variants specific names have been applied.

INTRODUCTION

Although many species of American larger Foraminifera were described and illustrated inadequately, subsequent studies have shown not only the fundamental characteristics by which the species could be recognized, but also the variation which can occur between individuals of the same species. However, there are still specific names in the literature which cannot be used satisfactorily because the characteristics of the types of these species are not known adequately, or the variation which may occur is not understood.

Cushman (1919) described from the West Indies a number of species of larger Foraminifera among which were *Nummulites antillea* (p. 51), *N. parvula* (p. 51), and *Orthophragmina antillea* (p. 55). Although Vaughan (1924, p. 787) recognized early that *N. antillea* belonged to another genus, this specific name has not been used since. The best illustrations of the internal structures of the types of these three species are those of *N. parvula* which is an *Amphistegina* (Cole, 1957*b*, p. 38). *O. antillea* is illustrated by an external view and two thin sections. At least one of the thin sections illustrating this species represents *Pseudophragmina* (*Proporocyclina*) *cushmani* (Vaughan) (Cole and Gravell, 1952, p. 723).

Certain Eocene species belonging to the genus *Operculinoides* were described and illustrated better than the species cited above, but they still require more study. Among these are: *Operculina oliveri* Cushman (1925,

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p. 298), *Operculina cushmani* Cole (1927, p. 23), and *Operculinella sabinensis* Cole (1929, p. 62). Moreover, the relationship between well-described species, such as, *Operculina ocalana* Cushman (1921*b*, p. 129), *Operculina vaughani* Cushman (1921*b*, p. 128), and *Nummulites floridensis* Heilprin (1885, p. 321) required additional study.

This study is an attempt to elucidate the characteristics of these and other species and to suggest their relationship to other species, certain of which were named later, but are obviously synonyms of earlier described species. When characters of species become known so that the species can be identified with certainty wherever it is encountered, it will be possible to use this species for correlation. At present many of these species are useless names in the literature, as the species is imperfectly known and recorded only from its type locality.

Many species of *Operculinoides* have been distinguished from other species by such statements as "*Operculinoides vaughani* has a somewhat similar form, but it is a larger species and has relatively fewer chambers" (Vaughan and Cole, 1941, p. 41) or "Sections show the septa to be sharply recurved, somewhat as in *Operculinoides antiguensis* and *O. semmesi*, but the curvature is not so abrupt, the coiling is less regular, and the test is consistently smaller and thicker in proportion to the diameter" (Barker, 1939, p. 314). Many other statements of this type could be cited.

Yet, the majority of such comparisons were made on observations of relatively few specimens and even fewer thin sections. Little attention has been given, moreover, to the reaction of individuals to environment. Thus, specimens recovered from fine-grained clastic deposits which normally have a different external appearance from others recovered from limestone have been given different specific names.

Many species are thus "form" species rather than natural species. Although it must be admitted that "form" species and even "form" genera must be recognized and are useful in paleontology, every attempt should be made to understand and evaluate species as biologic units so that geographic and stratigraphic distribution may be better understood. In too many cases "form" species have been designated because it was believed that the species must be restricted to a given stratigraphic unit, therefore, these specimens were given specific names and distinguished from other named species by subjectively evaluated characteristics.

The fact that certain species of larger Foraminifera may have longer stratigraphic ranges than formerly was assumed has been discussed by Cole

(1952, p. 4, 5) among others. Therefore, it is not unexpected to find representatives of *O. floridensis* occurring in sediments assigned both to the upper middle Eocene and the upper Eocene, and *Operculinoides dia* ranging throughout the Oligocene.

LOCALITIES OF THE FIGURED SPECIMENS

FLORIDA

Loc. 1. Ocala limestone on the bank of the Chipola River at Marianna, Jackson County.
1*a*. Roof and wall of cave exposed in road-cut on Florida State Road No. 1, about 150 yards east of bridge over Chipola River just east of Marianna, Jackson County. Locality 7 of Cole and Ponton (1930, p. 21).
2. United Brotherhood of Carpenters and Joiners well about 2 miles north of Lakeland, Polk County, at a depth of 250-258 feet.
3. Granberry well, southeast corner of the SW¼ of the NE¼ of Sec. 15, T. 15 N., R. 9W., Jackson County, at a depth of 220-240 feet.
3*a*. Same as loc. 3 at a depth of 240-260 feet.

MISSISSIPPI

4. Road below National Cemetery, Vicksburg.

TEXAS

5. 0.75 mile below Robinson's Ferry on the Sabine River, Sabine County.
6. Deering *et al* well No. 1 Freund, Grimes County, at a depth of 2700—2720 feet (cutting).

MEXICO (TAMPICO EMBAYMENT)

7. Guayabal formation, type locality, 12 kilometers west of Potrero del Llano.
8. Hacienda Romance, east side of Rio Moctezuma at Soledad.
9. Rio Panuco near Rancho Romance opposite El Chote.
10. Rio Tempoal 14 kilometers north of El Higo.
11. Bend on Rio Vinazco about 200 meters southwest of the Penn-Mex Fuel Company's camp, La Pita.

JAMAICA, B. W. I.

12. About one mile northwest of Port Maria, St. Mary Parish.

ST. BARTHOLOMEW, FRENCH WEST INDIES

13*a, b*. Northern slope of promontary separating Anse des Cayes and Baíe de St. Jean.
  13*a*. SB 18—coarse bedded compact algal limestone with rare *Camerina* (base somewhat tufaceous at the top of the vertical limestone cliff).
  13*b*. SB 19—coarse bedded *Lithothamium* and foraminiferal limestone with *Camerina, Discocyclina,* and *Asterocyclina* overlying SB 18.
13*c, d*. Promontory separating Anse des Lézards and Anse des Cayes on the north coast of the island.
  13*c*. SB 12—0.2 meters of marly tuff with matrix free specimens forming transition between the lower horizon of cross-bedded tuffs and the overlying limestones.
  13*d*. SB 13—small bands of brown marly tuff (1.2m. and 1m.) with matrix free specimens alternating with the massive limestone beds, directly overlying the lower horizon of cross-bedded tuffs.

14. At the bifurcation of the path leading from Gustavia to Anse de Cayes and to Colombier. SB 22—greenish conglomeratic tuffs with limestone nodules.

CUBA

15. Bermudez sta. 112—8.2 kilometers east of Colón, Matanzas Province.

TRINIDAD

16. Kugler loc. 11,398—Morne Diablo quarry (Cole, 1957, p. 32).

PANAMA CANAL ZONE

17. Woodring loc. 55—Panama Railroad, east side of cut southeast of Bohio Peninsula (Cole, 1952, p. 6).

DESCRIPTION OF SPECIES

Operculinoides floridensis (Heilprin) Pl. 18, figs. 1, 2, 7-16; Pl. 19, figs. 1, 2, 4, 5, 7-14; Pl. 20, figs. 5-9, 13-15, 17-20; Pl. 21; Pl. 22, figs. 4, 5.

1885. *Nummulites floridensis* Heilprin, Nat. Acad. Sci. Philadelphia, Proc., p. 321, 322, text fig.
1919. *Nummulites antillea* Cushman, Carnegie Inst. Washington, Publ. 291, p. 51, pl. 4, figs. 1, 2.
1921. *Operculina cookei* Cushman, U. S. Geol. Sur., Prof. Paper 128-E, p. 127, 128, pl. 18, figs. 1, 2.
1921. *Operculina vaughani* Cushman, *idem*, p. 128, pl. 19, figs. 6, 7.
1921. *Operculina ocalana* Cushman, *idem*, p. 129, pl. 19, figs. 4, 5; pl. 20, fig. 8.
1921. *Operculina floridensis* (Heilprin), Cushman, *idem*. p. 130, pl. 20, fig. 12.
1925. *Operculina oliveri* Cushman, Bull. Amer. Assoc. Petrol. Geol., vol. 9, No. 2, p. 298, 299, pl. 6, figs. 1, 2.
1927. *Operculina cushmani* Cole, Bull. Amer. Paleont., vol. 14, No. 51, p. 23, pl. 2, fig. 13.
1927. *Operculina bartschi plana* Cole, *idem*, p. 23, 24, pl. 2, fig. 20. Not *Operculina bartschi plana* Cushman, 1921*a*.
1935. *Operculina vaughani* Cushman, Gravell and Hanna, Jour. Paleont., vol. 9, No. 4, p. 334, pl. 29, figs. 6, 9, 12, 16-21.
1939. *Operculinoides oliveri* (Cushman), Barker, U. S. Nat. Mus., Proc., vol. 86, No. 3052, p. 318, 319, pl. 11, fig. 1; pl. 15, fig. 13.
1939. *Operculinoides vaughani* (Cushman), Barker, *idem*, p. 319, pl. 11, figs. 2, 3.
1941. *Operculinoides ocalanus* (Cushman), Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 38-40, pl. 8, figs. 8, 9; pl. 9, figs. 1-4; pl. 10, fig. 11.
1941. *Operculinoides soldadensis* Vaughan and Cole, *idem*, p. 40, 41, pl. 9, figs. 5-8; pl. 10, figs. 1, 2.
1941. *Operculinoides floridensis* (Heilprin), Cole, Florida Geol. Sur., Bull. 19, p. 30, 31, pl. 9, fig. 8; pl. 10, figs. 1-3.
1941. *Operculinoides ocalanus* (Cushman), Cole, *idem*, p. 31, 32, pl. 10, figs. 4-7.
1951. *Nummulites* (*Operculinoides*) *oliveri* (Cushman), Cizancourt, Soc. Géol. France, Mém. 64, n.s., vol. 30, pl. 3, fig. 6.
1951. *Nummulites* (*Operculinoides*) *jennyi* Barker, Cizancourt, idem. pl. 3, fig. 10.
1952. *Operculinoides ocalanus* (Cushman), Cole, U. S. Geol. Sur., Prof. Paper 244, p. 10, pl. 2, figs. 5-11.
1952. *Operculinoides vaughani* (Cushman), Cole, *idem*, p. 11, pl. 2, figs. 12-16.
1956. *Operculinoides cushmani* Cole, Cole, Bull. Amer. Paleont., vol. 36, No. 158, p. 214, pl. 30, figs. 11-13; pl. 31, figs. 5, 6.

The synonomy given above is not complete, but it contains most of the specific names which have been applied to this species. As this study developed, the middle Eocene species (*O. antillea, O. cushmani, O. oliveri* and *O. bartschi plana* of Cole, not Cushman) were studied first. Eventually, it was concluded that these names had been applied to one species. Later, certain upper Eocene species (*O. cookei, O. floridensis, O. ocalana,* and *O. vaughani*) were studied, and it became apparent that these names had been applied to one species.

However, as comparisons were made between the suites of middle and upper Eocene specimens, there did not seem to be any single character or combination of characters by which the two basic species which were recognized in the preliminary study could be distinguished. Thus, all these specimens are placed in a single species which has been designated *Operculinoides floridensis* (Heilprin), 1885, as this was seemingly the first name to be used. This species has a stratigraphic range from middle into the upper Eocene.

The discussion which follows will be divided into three sections with the middle Eocene specimens treated first, followed by remarks on the upper Eocene specimens and, finally, the reasons for combining the basic species will be given.

MIDDLE EOCENE SPECIMENS

Cushman (1919, p. 51, pl. 4, figs. 1, 2) gave the name *Nummulites antillea* to specimens, the types of which came from USGS station 6924, a "bed of limestone at top of described section, point on northwest side of St. Jean Bay, St. Bartholomew, collected by T. W. Vaughan." The type specimen is a large, apparently microspheric individual, with a maximum diameter of about 16 mm. and the surface somewhat weathered. Cushman illustrated also a part of a median section of a specimen from another locality.

Vaughan (1924, p. 787) listed this species and expressed the opinion that it should be transferred to the genus *Operculina.* After this one casual reference to this species, it has not been discussed apparently in detail by any other author.

In 1925 Cushman (p. 298) described a foraminiferal fauna from Mexico, from the "east bank of Moctezuma River, on the eastern portion of the bend which makes its way into Hacienda Romance and near the mouth of the Rio Tamuin." Among the species which he described was *Operculina oliveri.* He stated (p. 299) that, "This species belongs in the general group of *Operculina antillea* Cushman, *O. cookei* Cushman, and *O.*

vaughani Cushman. It is smaller than the first and in many characters is midway between the last two. *O. oliveri*, however, has more chambers in the adult than any of the others, the walls and sutures are thicker, and the whole test heavier than in either *O. cookei* or *O. vaughani*."

Barker (1939, p. 318) redescribed and figured an external view and a median section of specimens that are probably topotypes of *Operculina oliveri*, and he transferred this species to the genus *Operculinoides*.

Cole (1927, p. 23) named a species from the type locality of the Guayabal formation of the Tampico Embayment area *Operculina cushmani*. He referred other specimens from this same locality to *Operculina bartschi plana* Cushman (1921*a*, p. 377), a Recent species described from the Philippine Islands. However, he recognized that these two species came from approximately the same horizon within the Guayabal formation as did *Operculina oliveri* because of the associated smaller Foraminifera.

Although Barker (1939, p. 319) considered that *O. cushmani* was probably the same as *O. oliveri*, he qualified this assignment by writing". . . it is possible that Cole also included in his species forms referred by the writer to *Operculinoides vaughani* (Cushman), q.v." Barker (1939, pl. 11, figs. 2, 3) figured two specimens from the Guayabal type locality which he identified as *Operculinoides vaughani* (Cushman). These specimens according to Barker differ "from *O. oliveri* (Cushman) in being of smaller size, rather more tightly coiled, and narrower and more numerous chambers and in having more regularly beaded sutures." Cole (1944, p. 48) stated that "These specimens are not *O. vaughani* which is confined to the upper Eocene, but represent *O. cushmani* (Cole)."

In 1951 Mrs. Cizancourt illustrated (pl. 3, figs. 6, 9) specimens from the middle Eocene of Venezuela which she referred to *Nummulites* (*Operculinoides*) *oliveri* and others which she identified with *Nummulites* (*Operculinoides*) *jennyi* (Barker).

Cole (1956, p. 214, pl. 30, figs. 11-13; pl. 31, figs. 5, 6) illustrated specimens from the middle Eocene of Jamaica, B.W.I., which he identified with *O. cushmani*. For comparison with the Jamaican specimens he illustrated a topotype of *O. cushmani*.

Thus, four names, *O. antillea, O. cushmani, O. oliveri* and *O. bartschi plana,* were established in the literature for middle Eocene species of *Operculinoides* which differ from each other in a slight degree when the type illustrations are compared. However, they seemingly come from approximately the same horizon in the middle Eocene. In all the descriptions of these species little, if any, emphasis was placed on the internal characters which can be seen only in thin section.

Inasmuch as the writer has had in his possession for a number of years numerous thin sections made from samples collected by the late Dr. Alfred Senn in St. Bartholomew, a study was made to discover if any of these thin sections had specimens which could be identified as *O. antillea.* To supplement observations made on these thin sections Dr. Raymond Douglass of the U. S. Geological Survey kindly sawed the limestone fragment on which the type specimen of *O. antillea* appears and sent the writer the piece which was removed.

Although the thin sections in the Senn collection did not contain any accurately oriented thin sections of *O. antillea,* there were numerous unoriented sections (Pl. 19, fig. 7; Pl. 21, figs. 2, 8, 9, 12, 14, 15) of which certain ones (Pl. 21, figs. 8, 9, 14) immediately were identified as *O. antillea.* The certainty of this identification was established when a polished surface of the fragment removed from the block on which the type appears showed similar unoriented transverse and median sections.

As transverse sections of topotypes of *O. oliveri* and as neither transverse nor median sections of *O. cushmani* had been published, thin sections of these were prepared. In addition thin sections were made of specimens from two other Mexican localities which were suspected of being either *O. cushmani* or *O. oliveri,* although most of these specimens were much smaller than topotypes of *O. oliveri.*

As this study progressed Mr. E. Robinson of the Jamaican Geological Survey sent a sample which contained among other species of larger Foraminifera specimens which appeared to be *O. antillea,* although these specimens were smaller than the type specimen. These Jamaican specimens are illustrated (Pl. 21, figs. 5, 10, 13; Pl. 22, figs. 4, 5). The largest Jamaican specimen had a diameter of 6.7 mm., and the sutures are raised and prominent.

The late Mr. Donald Gravell had sent many years ago from a Texas well specimens which he had identified tentatively as *O. cushmani.* Two of these specimens (Pl. 20, figs. 8, 15) were sectioned for comparison with the Mexican specimens.

As the illustrations and the measurements demonstrate, all the specimens referred to *O. antillea, O. cushmani,* and *O. oliveri* form a completely integrated series and represent one species. To these three may be added the Mexican specimens which Cole identified as *O. bartschi plana.*

Measurements of middle Eocene specimens assigned in the preliminary study to *O. antillea* are given on pages 187 to 189.

SPECIMENS FROM ST. BARTHOLOMEW

In the specimens from St. Bartholomew the best median section (Pl. 21, fig. 12) of a probable megalospheric specimen has a height of about 4 mm. and a width of about 2.9 mm. There are 19 chambers in the final volution. The best median section (Pl. 21, fig. 14) of a larger specimen, which could be either megalospheric or microspheric, has an incomplete height of 5.9 mm.

The best transverse section (Pl. 21, fig. 15) of a small specimen has a height of 2.4 mm. and a thickness through the center of 0.4 mm. A larger specimen (Pl. 19, fig. 7) has a height of 4.37 mm. and a thickness through the center of 0.75 mm. Another specimen (Pl. 21, fig. 2) which is apparently sectioned through the center has a height of 4.15 mm. and a thickness through the center of 0.85 mm.

The sections which on size and appearance would correspond seemingly to one made from specimens similar to the type specimen of *O. antillea* are illustrated as figures 8, 9, Plate 21. One of these sections is through the initial part of the test. It has a height of 5.0 mm. and a thickness of 0.75 mm. The other section through the margin of the test has a length of 6.0 mm., a thickness between the nodes of 0.2 mm., and a thickness at the nodes of 0.35 mm.

Several specimens which are not illustrated resembled the marginal section described above except in dimensions. One of these had a length of 5.1 mm., a thickness between the nodes of 0.14 mm., and a thickness at the nodes of 0.33 mm. Another specimen had a thickness between the nodes of 0.1 mm. and at the nodes of 0.25 mm. Thus, there is considerable variation in dimensions between specimens.

MEXICAN SPECIMENS

Median Sections

Locality	7(1)		10	9				8(2)	After Barker (2) (1939)
Specimen	Pl. 20, fig. 14	Pl. 19, fig. 12	Pl. 20, fig. 17	Pl. 20, fig. 13	Pl. 20, fig. 18	Pl. 20, fig. 19	Pl. 20, fig. 20	Pl. 19, fig. 11	Pl. 15, fig. 3
Height mm.	1.75	2.5	1.9	1.7	2.47	2.6	3.8	4.9	4.45
Width mm.	1.5	2.0	1.55	1.4	2.1	2.5	3.1	4.65	3.85
Embryonic chambers:									
Diameters of initial chamber μ	80x85	70x70	110x130	90x95	110x120	110x160	110x120	90x80	—
Diameters of second chamber μ	60x130	40x70	70x170	50x120	80x120	60x145	70x150	60x120	—
Distance across both chambers μ	150	125	200	145	200	200	195	160	185
Coils	2⅛	2¾	2	2⅛	2⅛	2½	2½	3¼	3
Chambers in first volution	7	6	5	6	7	6	5	5	6
Chambers in final volution	17	18	16	17	19	26	23	33	25
Total number of chambers	28	35	21	26	30	38	37	71	51

(1) Specimens previously called *O. cushmani* Cole
(2) Specimens previously called *O. oliveri* Cushman

MEXICAN SPECIMENS (CONTINUED)

Transverse Sections

Locality	7(1)					10	9				8(2)	
Specimen		Pl. 21, fig. 4	Pl. 20, fig. 9	Pl. 19, fig. 2	Pl. 21, fig. 11	Pl. 20, fig. 7		Pl. 20, fig. 5	Pl. 19, fig. 9	Pl. 20, fig. 6	Pl. 21, fig. 6	Pl. 19, fig. 4
Height .... mm.	1.8	1.75	2.39	2.2	2.5	1.75	2.1	3.1	3.0	3.4	3.9	5.75
Thickness at center .... mm.	0.31	0.42	0.4	0.41	0.65	0.38	0.35	0.5	0.45	0.52	0.4	0.55
Diameter umbonal plug ....µ	90	120	150	230	300	110	190	300	150	180	160	200

(1) Specimens previously called *O. cushmani* Cole
(2) Specimens previously called *O. oliveri* Cushman

JAMAICAN SPECIMENS

Median Sections

Locality	12		
Specimen	Pl. 21, fig. 13	Pl. 22, fig. 4	Pl. 22, fig. 5
Height mm.	4.5	5.1	6.2
Width mm.	3.95+	3.9	4.6
Embryonic chambers:			
Diameters of initial chamber μ	170x220	70x80	140x170
Diameters of second chamber μ	120x220	65x110	110x200
Distance across both chambers μ	320	150	270
Coils	3	3+	3⅞
Chambers in first volution	7	8	7
Chambers in final volution	23	22	21
Total number of chambers	47	47	55

Transverse Sections

Locality	12	
Specimen	Pl. 21, fig. 10	Pl. 21, fig. 5
Height mm.	5.6	6.7
Thickness at center mm.	0.72	0.9
Diameter of umbonal plug μ	150	240

ASSOCIATED FORAMINIFERAL FAUNAS

Mexican localities.—

Loc. 7. See Cole, 1927.
8. See Cushman, 1925.
9, 10. Smaller Foraminifera only, all of which occur at locs. 7 and 8.

St. Bartholomew localities.—

13*a*. *Amphistegina parvula* (Cushman)
Asterocyclina habanensis Cole and Bermudez
penonensis Cole and Gravell
Camerina guayabalensis Barker
Ferayina coralliformis Frizzell
Pseudophragmina (*Proporocyclina*) *cushmani* (Vaughan)
psila (Woodring)
teres Cole and Gravell

13*b*. *Amphistegina parvula* (Cushman)
Asterocyclina habanensis Cole and Bermudez
monticellensis Cole and Ponton
penonensis Cole and Gravell
Camerina guayabalensis Barker
Discocyclina (*Discocylina*) *marginata* (Cushman)
Eoconuloides wellsi Cole and Bermudez
Fabiania cubensis (Cushman and Bermudez)
Helicostegina gyralis Barker and Grimsdale
Lepidocyclina (*Polylepidina*) *antillea* Cushman
Pseudophragmina (*Proporocyclina*) *convexicamerata* Cole and Gravell
cushmani (Vaughan)
teres Cole and Gravell

14. *Asterocyclina habanensis* Cole and Bermudez
penonensis Cole and Gravell
Cymbalopora irregularis Keijer
Lepidocyclina (*Polylepidina*) *antillea* Cushman
Pseudophragmina (*Proporocyclina*) *teres* Cole and Gravell

Jamaican locality.—

12. *Asterocyclina monticellensis* Cole and Ponton
    Dictyoconus cookei (Moberg)
    Eulinderina semiradiata Barker and Grimsdale
    Fabiania cubensis (Cushman and Bermudez)
    Pseudophragmina (*Proporocyclina*) *convexicamerata* Cole and Gravell
    cushmani (Vaughan)
    compacta Cole and Gravell

ECOLOGICAL IMPLICATIONS

The Mexican specimens occur in clastic sediments, mainly a clay-shale, whereas those from St. Bartholomew occur in limestone, and those from Jamaica were found in marl. The Mexican specimens at locality 7 are associated with *Pseudophragmina* (*Proporocyclina*) *perpusilla* (Vaughan), extremely rare specimens of *Lepidocyclina* and rather abundant specimens of smaller Foraminifera. The specimens at localities 8 and 9 occur with smaller Foraminifera, but other kinds of larger Foraminifera were not found. The specimens from St. Bartholomew are accompanied by numerous and varied kinds of larger Foraminifera. The sample from Jamaica is dominated by *Pseudophragmina* (*Proporocyclina*) *compacta* Cole and Gravell. However, *Operculinoides* occurs in abundance, and there are other kinds of larger Foraminifera.

These associations, as well as the abundance and size of the specimens, suggest that there were ecological controls. Locality 7 with few specimens, all of which are small in size, was the least favorable for the development of larger Foraminifera. The limestone of St. Bartholomew was deposited under conditions which were most favorable with the next best environment, the one which occured in Jamaica.

Thus, the Mexican specimens are normally smaller, and their tests are more delicate and fragile. The largest, most robust tests occur in the favorable environment which occured in St. Bartholomew. The Jamaican specimens developed in an environment which more nearly resembled that of St. Bartholomew.

UPPER EOCENE SPECIMENS

Heilprin's (1885) description of *Nummulites floridensis* is inadequate, but when sufficient Floridian samples are examined it is possible to determine fairly exactly the kind of specimens he was describing. Cushman (1921*b*, pl. 20, fig. 12) illustrated a probable topotype which shows the exterior excellently.

Cole (1941, pl. 10, fig. 3) illustrated from a well a Floridian specimen which externally is a duplicate of the specimen illustrated by Cushman. In addition (Cole, 1941, pl. 9, fig. 8; pl. 10, figs. 1, 2) gave illustrations of the internal features of the specimens from this well. Additional illustrations of specimens from this well are given as figure 1, Plate 18 and figures 10, 14, Plate 19.

At the same time Cole (1941, pl. 10, figs. 4-7) identified smaller specimens from the same sample as *Operculinoides ocalanus* (Cushman). Although he recognized (p. 31) that these specimens also resembled those called *O. floridensis*, he believed at that time that a separation was possible.

Cushman (1921*b*) had named other specimens from the Ocala limestone *Operculina cookei, O. ocalana,* and *O. vaughani.* The types of both *O. cookei* and *O. vaughani* are natural median sections, and that of *O. ocalana* is an external view.

Gravell and Hanna (1935) in a study of larger Foraminifera from the Moody's Branch marl stated (p. 333): "Our specimens of *Operculina* resemble *Operculina ocalana* in size, number of chambers, and general form, but appear to differ in that they are more delicately constructed, the walls of the test being thinner." They referred the specimens to *O. vaughani* and gave a sequence of excellent photographs.

The specimens from the Moody's Branch marl normally are preserved excellently and have the appearance of specimens dredged from the Recent seas. Specimens from the Ocala limestone have dull white tests which resemble the limestone matrix from which they came. If the type of preservation is ignored, there does not appear to be any fundamental character which will distinguish specimens from the Ocala limestone normally identified as *O. ocalana* from those from the Moody's Branch marl called *O. vaughani.*

The well-preserved specimens from the Moody's Branch marl often have more consistent beading along the sutures (Pl. 18, figs. 11, 12), whereas many specimens from the Ocala limestone do not have this beading

(Pl. 18, fig. 9). However, other specimens do have beading (Pl. 18, figs. 7, 10) which is similar to that which is found more typically on the specimens from the Moody's Branch marl. It is suggested that the degree of beading is an individual rather than a specific character and is controlled to some extent by environmental factors.

Although little information is available regarding *O. cookei,* it appears to be within the range of the *O. ocalana—O. vaughani* series.

In 1941 Vaughan and Cole (p. 37) erected the name *O. soldadensis* for upper Eocene specimens from Trinidad. They compared this species with *O. ocalana* but separated it from that species on the number of chambers in the final volution.

All of these species have costate surfaces, the spire expands in the final volution, the chambers are long, narrow, the chamber walls recurve regularly, the final whorl is expanded into a marked, thin flange, and the test in the umbonal area is normally compressed, although some specimens may have a small umbo.

They have been separated from each other on size, degree of development of the costae, development of sutural beading, and the number of chambers particularly in the final volution. These are individual rather than specific characters. It is possible to arrange these species in a completely integrated series representing only one species.

Measurements of upper Eocene specimens assigned in the preliminary study to *O. floridensis* follow:

FLORIDIAN AND TEXAN SPECIMENS

Median Sections

Locality	After Cole (1941)			2	1	5
Specimen	Pl. 10, fig. 5	Pl. 10, fig. 6	Pl. 10, fig. 1	Pl. 19, fig. 10	Pl. 19, fig. 13	Pl. 19, fig. 1
Height mm.	2.8	3.2	4.5	5.1	4.45	3.8
Width mm.	2.5	2.7	3.9	4.3	3.8	3.1
Diameters of initial chamber μ	—	—	—	90x100	100x100	70x70
Diameters of second chamber μ	—	—	—	60x140	80x170	50x110
Distance across both chambers μ	—	—	—	170	210	120
Number of coils	2½	3	3	3¼	2¾	2¾
Chambers in first volution	9	—	9	7	6	6
Chambers in final volution	22	31	29	29	20	21
Total number of chambers	43	62+	55	64	43	38

Transverse Sections

Locality	After Cole (1941)	2	5	1	
Specimen	Pl. 10, fig. 2	Pl. 19, fig. 14	Pl. 19, fig. 5	Pl. 19, fig. 8	Pl. 21, fig. 7
Height mm.	4.6	4.8	3.9	3.6	4.1
Thickness at center mm.	0.72	0.62	0.8	0.78	0.6
Diameter of umbonal plug μ	—	300	420	300	300

ECOLOGICAL IMPLICATIONS

These are the same as suggested for the middle Eocene specimens. Specimens previously called *O. vaughani* developed under ecological conditions which favored the formation of delicate, highly ornamented tests, whereas those called *O. ocalana* lived in an environment which seemingly caused the development of strongly costate tests. Specimens called *O. floridensis* represent larger specimens which grade into the kind called *O. ocalana.*

COMBINATION OF THE MIDDLE AND UPPER EOCENE SPECIES

The illustrations should be compared in the order given below to understand the complete gradation of the previously recognized species into one species:

O. bartschi plana to *O. cushmani* to *O. oliveri* to *O. antillea.*

Median Sections

Pl. 20, figs. 17, 18, 13, 14, 20; Pl. 21, fig. 12; Pl. 22, fig. 4; Pl. 19, fig. 11; Pl. 21, fig. 14.

Transverse Sections

Pl. 21, fig. 4; Pl. 20, fig. 9; Pl. 21, fig. 15; Pl. 20, figs. 5, 6; Pl. 21, figs. 6, 10, 3, 2, 8, 9.

O. ocalana to *O. vaughani* to *O. floridensis*

Median Sections

Pl. 19, figs. 13, 1; Cole, 1941, pl. 10, figs. 5, 6; Pl. 19, fig. 10.

Transverse Sections

Pl. 19, fig. 8; Pl. 21, fig. 7; Pl. 19, figs. 5, 14.

O. floridensis to *O. oliveri*

Median Sections

Pl. 19, figs. 10, 11.

Transverse Sections

Pl. 19, figs. 14, 4.

Illustrations given in other publications may be inserted in the suggested series above for completeness, but the illustrations given prove that only one species can be recognized.

Operculinoides sabinensis (Cole) Pl. 18, figs. 3-6; Pl. 19, figs. 3, 6; Pl. 20, figs. 1-4, 10-12, 16

1929. *Operculinella sabinensis* Cole, Bull. Amer. Paleont., vol. 15, No. 56, p. 62, pl. 2, figs. 5, 6.

1938. *Operculinoides sabinensis* Cole, Cole, Florida Geol. Sur., Bull. 16, p. 38, pl. 5, figs. 1-7.

1939. *Operculinoides prenummulitiformis* Barker, U. S. Nat. Mus., Proc., vol. 86, No. 3052, p. 311, pl. 12, figs. 1, 2; pl. 17, fig. 4; pl. 21, fig. 2.

The type illustrations of this species from the middle Eocene of Texas are not satisfactory. Cole (1938, p. 38) later redescribed and illustrated this species using specimens from Florida for this purpose as additional specimens from the type locality could not be found. However, as these specimens from Florida were similar to the type, and as they were associated with *Lepidocyclina* (*Polylepidina*) *antillea*, it was believed they represented the same species.

Barker (1939) published an important article on Mexican species of camerinids in which among other species he described *O. prenummulitiformis* from the Guayabal formation (upper middle Eocene) of Mexico. Unfortunately, Cole's second article (1938) on *O. sabinensis* reached Barker during the time his Mexican paper was in press.

In the collection available to the writer specimens from locality 11 appeared to be the same as *O. prenummulitiformis* (compare fig. 4, Pl. 18 with Barker's (1939) illustrations, fig. 1, pl. 12). Moreover, certain of these specimens (fig. 6, Pl. 18) compared favorably with the type illustration and specimens from Florida assigned to *O. sabinensis*. Therefore, it appears as if these two species should be combined.

Median Sections of *Operculinoides sabinensis*

Locality	11			3*a*	3	After Barker (1939)
Specimen	Pl. 20, fig. 16	Pl. 20, fig. 10	Pl. 20, fig. 12	Pl. 20, fig. 11	Pl. 19, fig. 3	Pl. 17 fig. 4
Height .... mm.	2.57	2.75	3.1	2.95	2.55	2.6
Width ....mm.	2.3	2.1	2.65	2.6	2.4	2.35
Embryonic chambers: Diameters of initial chamber .... μ	90x100	80x80	70x70	80x80	90x110	—
Diameters of second chamber ....μ	90x110	40x120	30x70	50x100	90x100	—
Distance across both chambers...μ	160	120	100	140	160	—
Number of volutions	4	4	4	3½	3¾	3½
Chambers in first volution	8	7	8	7	8	7
Chambers in final volution	24	25	26	22	23	23
Total number of chambers	71	69	70	54	58	57

Transverse Sections of *Operculinoides sabinensis*

Locality	11			3	3*a*	After Barker (1939)
Specimen	Pl. 20, fig. 1	Pl. 20, fig. 2	Pl. 20, fig. 3	Pl. 20, fig. 4	Pl. 19, fig. 6	Pl. 21, fig. 2
Height ....mm.	3.0	2.7	2.25	2.75	2.35	2.9
Thickness at center ....mm.	0.5	0.72	0.4	0.6	0.5	0.45
Diameter of umbonal plug ......μ	150	230	—	140	—	—

Operculinoides dia (Cole and Ponton) Pl. 22, figs. 1-3; Pl. 24, fig. 5; Pl. 25, figs. 3-13, 16

1930. *Operculinella dia* Cole and Ponton, Florida Geol. Sur., Bull. 5, p. 37, pl. 6, fig. 7; pl. 7, figs. 11-13.

1936. *Operculinoides vicksburgensis* Vaughan and Cole, U. S. Nat. Mus., Proc., vol. 83, No. 2996, p. 493, pl. 37, figs. 1-3.

1936. *Operculinoides semmesi* Vaughan and Cole, *idem*, p. 491, 492, pl. 37, figs. 10-14; pl. 38, figs. 1, 2, 5, 6.

1936. *Operculinoides antiguensis* Vaughan and Cole, *idem*, p. 492, 493, pl. 38, figs. 7-10.

1936. *Operculinoides forresti* Vaughan and Cole, *idem*, p. 493, pl. 37, figs. 1-3.

1937. *Operculinoides ellisorae* Gravell and Hanna, Jour. Paleont., vol. 11, No. 6, p. 522, 523, pl. 60, figs. 1-6.

1937. *Operculinoides howei* Gravell and Hanna, *idem*, p. 523, 524, pl. 61, figs. 2-6.

1938. *Operculinoides forresti* Vaughan and Cole, Cole, Florida Geol. Sur., Bull. 16, p. 37, pl. 5, figs. 8-13.

1939. *Operculinoides muiri* Barker, U. S. Nat. Mus., Proc., vol. 86, No. 3052, pl. 14, fig. 4; pl. 20, fig. 1; pl. 22, fig. 1.

1939. *Operculinoides antiguensis* Vaughan and Cole, Barker, *idem*, p. 313, 314, pl. 14, figs. 1, 2; pl. 16, fig. 3; pl. 17, fig. 1; pl. 21, figs. 10-11.

1939. *Operculinoides semmesi* Vaughan and Cole, Barker, *idem*, p. 314, pl. 19, figs. 1-6.

1939. *Operculinoides palmarealensis* Barker, *idem*, p. 314, pl. 13, fig. 8; pl. 18, fig. 1; pl. 22, figs. 7, 8.

1939. *Operculinoides vicksburgensis* Vaughan and Cole, Barker, *idem*, p. 318, pl. 12, fig. 6; pl. 18, fig. 2; pl. 19, figs. 8, 9.

1941. *Operculinoides bullbrooki* Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 44, 45, pl. 11, figs. 6, 7; pl. 12, figs. 4, 5.

1941. *Operculinoides semmesi* Vaughan and Cole, Vaughan and Cole, *idem*, p. 50, 51, pl. 14, figs. 5-9; pl. 15, figs. 1, 2, 9.

1941. *Operculinoides semmesi ciperensis* Vaughan and Cole, *idem*, p. 51-53, pl. 15, figs. 3-8.

1941. *Operculinoides vicksburgensis* Vaughan and Cole, Vaughan and Cole, *idem*, p. 53, 54.

1944. *Operculinoides antiguensis* Vaughan and Cole, Cole, Florida Geol. Sur., Bull. 26, p. 40-42, pl. 6, figs. 13, 14.

1944. *Operculinoides dius* (Cole and Ponton), Cole, *idem*, p. 42, 43, pl. 6, fig. 6; pl. 19, figs. 4, 10, 12, 13.

1944. *Operculinoides vicksburgensis* Vaughan and Cole, Cole, *idem*, p. 49, 50, 51, pl. 3, figs. 7, 10; pl. 6, figs. 1-5, 11, 12, 15, 17, 18; pl. 19, fig. 11.

1945. *Operculinoides vicksburgensis* Vaughan and Cole, Cole, Florida Geol. Sur., Bull. 28, p. 26-30, pl. 1, figs. 12, 13; pl. 5, figs. 1-10; pl. 11, figs. 4, 5.

1957. *Amphistegina bullbrooki* (Vaughan and Cole), Cole, Bull. Amer. Paleont., vol. 38, No. 166, p. 37, 38, pl. 5, figs. 6, 7.

Barker (1939, p. 314) expressed doubt whether *O. antiguensis* and *O. semmesi* represented separate species. Gravell and Hanna (1937, p. 524) stated that *O. howei* and *O. ellisorae* were close to *O. vicksburgensis*, and that *O. howei* resembled *O. semmesi*. Cole (1944, p. 40) placed *O. howei* in the synonomy of *O. antiguensis* and at the same time (1944, p. 49) placed *O. muiri* in the synonomy of *O. vicksburgensis*. Therefore, the validity of several of these specific names has been questioned.

Later, Cole (1945, p. 26) restudied specimens of *O. vicksburgensis* and *O. muiri* and concluded that these represented only one species. At that time Cole (1945, pl. 5, figs. 1, 4) demonstrated that individuals of *O. vicksburgensis* from a single population varied from compressed to lenticular shape as seen in transverse section.

Earlier, Gravell and Hanna (1937, p. 524) had written " . . . from the type Byram marl. Both *O. vicksburgensis* Vaughan and Cole and *O. dia* (Cole and Ponton) are present in the material." However, Cole in his study did not recognize that the compressed individuals which he assigned to *O. vicksburgensis* were the same as *O. dia.*

As the present study progressed the writer arranged a large suite (over 200 specimens) from the type locality of *O. vicksburgensis* in a continuous series. This series ranged from compressed individuals (*O. dia, O. forresti, O. bullbrooki*) to moderately inflated individuals (*O. semmesi, O. ellisorae, O. muiri*) to strongly inflated individuals (*O. howei, O. antiguensis*). The type transverse section of *O. vicksburgensis* was made from a specimen intermediate between *O. bullbrooki* and *O. semmesi.* Thus, nine specific names and one varietal name have been applied to one species.

Sufficient illustrations have been published so that anyone interested can duplicate the results obtained from observation on actual specimens by arranging these illustrations in a continuous series.

Although median sections were not made, several new transverse sections were prepared. These are illustrated on Plate 25. The series should be compared in the following order: 1) topotype of *O. dia,* fig. 4; 2) small topotype specimen of *O. vicksburgensis,* fig. 7; 3) large topotype specimen of *O. vicksburgensis,* fig. 6; 4) compressed specimen of *O. bullbrooki,* fig. 9; 5) moderately inflated specimen of *O. vicksburgensis,* fig. 13; 6) inflated specimen of *O. vicksburgensis,* fig. 8; 7) inflated specimen of *O. semmesi,* fig. 5.

Most of the compressed specimens have small embryonic chambers and are seemingly the microspheric forms, whereas the inflated specimens (fig. 3, Pl. 25) are megalospheric forms. Certain of the microspheric specimens resemble externally and internally certain large specimens of *Amphistegina* and could readily be mistaken for specimens that should be referred to that genus. However, the symmetry and apertures (fig. 12, Pl. 25) of the inflated specimens are the same as those found in *Operculinoides*.

Although the question might be raised that there are two genera represented in these specimens, it is not considered to be so as the type of the chamber walls, the curvature of the sutures and other features are constant between specimens of the two types, therefore, they are microspheric and megalospheric.

Comments.—Four new illustrations (fig. 1, 2, 14, 15, Pl. 25) of *Operculinoides panamensis* (Cushman) are given for comparison with *O. dia.* These small *Operculinoides* are similar to *O. dia,* but seemingly are a distinct species. Careful study of these illustrations, as well as those given by Vaughan and Cole (1941, pl. 10, figs. 13-16; pl. 11, figs. 1-5) and Cole (1952, pl. 2, figs. 1-4), will demonstrate the differences by which *O. panamensis* may be separated from *O. dia. O. panamensis* has an exceptional well-developed marginal cord (fig. 15, Pl. 25).

However, it should be recorded that Vaughan and Cole (1941, p. 44) stated concerning *O. bullbrooki* " . . . there is no definitely marked axial tubercle as in *O. panamensis* and *O. tamanensis.*" These specimens do have an umbonal plug which shows clearly in figure 9, Plate 25. If the type illustration (fig. 7, pl. 11) of this species given by Vaughan and Cole (1941) is examined with a hand lens similar umbonal plugs may be observed with the larger one on the left side. The umbonal plugs do not show as distinct in their illustration as in the adjacent illustration of *O. tamanensis* because the thin section of *O. bullbrooki* was thinner, and the walls of the test were not stained.

Such statements as these, here proven wrong, indicate how incompletely many species were described and the necessity for their revaluation by means of numerous thin sections. It also demonstrates why so many specific names were erected, often on non-existent differences, whereas fundamental relationships were ignored.

Stratigraphic range.—In a study of variation in *Lepidocyclina* Cole (1957*b*) demonstrated that *Lepidocyclina mantelli, L. forresti* and *L. supera* should be combined into a single species ranging in Florida from the Marianna limestone into the Suwannee limestone. The range of *O. dia* is the same with specimens from the Marianna limestone (*O. dia*) and those from the Suwannee limestone (*O. vicksburgensis*) combined into a single species.

Amphistegina parvula (Cushman) Pl. 25, figs. 17-19

1919. *Nummulites parvula* Cushman, Carnegie Inst. Washington, Publ. 291, p. 51, pl. 4, figs. 3-6.

1934. *Amphistegina lopeztrigoi* D. K. Palmer, Mem. Soc. Cubana Hist. Nat., vol. 8, No. 4, p. 255, pl. 15, figs. 6, 8.

1952. *Amphistegina lopeztrigoi* D. K. Palmer, Cole and Gravell, Jour. Paleont., vol. 26, No. 5, p. 714, pl. 91, figs. 6-8 (references).

As Cole (1957*b*, p. 37) stated, it is easy to confuse certain species of *Amphistegina* either with *Camerina* or *Operculinoides*. Cushman's illustrations of *Nummulites parvula* show clearly that it should be referred to the genus *Amphistegina*. Moreover, in the Senn collection from the middle Eocene limestone from St. Bartholomew there are numerous matrix-free specimens, as well as those in the thin sections, which are identical with the specimens figured by Cushman.

It is impossible to distinguish these specimens from St. Bartholomew from topotype specimens of *A. lopeztrigoi* from Cuba, therefore, the two species are combined.

Associated species.—Dictyoconus americanus (Cushman), *Fabiania cubensis* (Cushman and Bermudez), and *Lepidocyclina* (*Polylepidina*) *antillea* Cushman.

Lepidocyclina (Lepidocyclina) asterodisca Nuttall Pl. 22, fig. 6; Pl. 23; Pl. 24, figs. 6, 7

1932. *Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall, Jour. Paleont., vol. 6, p. 34, 35, pl. 7, figs. 5, 8; pl. 9, fig. 10.

1952. *Lepidocyclina* (*Lepidocyclina*) *asterodisca* Nuttall, Cole, U. S. Geol. Sur., Prof. Paper 244, p. 17, 18, pl. 17, fig. 4 (references).

Several years ago Dr. Pedro J. Bermudez sent me a Cuban sample (loc. 15) with abundant specimens of this species from the Cuban Oligocene. Selected specimens from this sample are illustrated to demonstrate the variation in size, shape, and number of rays which may occur in individuals in a single population.

The specimens with rays are megalospheric specimens, but in this sample there are numerous large, circular, compressed lenticular specimens without trace of rays either externally or in the arrangement of the equatorial chambers. These specimens are microspheric, and without question represent the sexual generation, whereas the megalospheric specimens with rays are the asexual generation.

The Cuban specimens (Pl. 23, figs. 2, 6, 7) should be compared with Nuttall's illustrations (1932, pl. 7, figs. 5, 8) of *L.* (*L.*) *asterodisca* for external appearance, and the equatorial section (Pl. 24, fig. 7) should be compared to his illustration (1932, pl. 9, fig. 10) of an equatorial section. In a similar manner the specimens (Pl. 23, figs. 1, 4, 5) should be compared with Gorter and Van der Vlerk's illustration (1932, pl. 11, fig. 5) of *L.* (*L*) *falconensis.* Finally, the specimens (Pl. 23, figs. 2, 6) should be compared with Gravell and Hanna's illustrations (1937, pl. 65, figs. 4, 5) of *L.* (*L.*) *texana.*

Associated species.—Heterostegina israelskyi Gravell and Hanna (abundant) ; *Operculinoides dia* (Cole and Ponton) (common). *H. israelskyi* (Pl. 24, figs. 1-4) is not discussed as Cole (1957*a*, p. 327) has given recently a key to American Oligocene species of *Heterostegina.*

Asterocyclina penonensis Cole and Gravell Pl. 22, fig. 7; Pl. 25, fig. 20

1952. *Asterocyclina penonensis* Cole and Gravell, Jour. Paleont., vol. 26, No. 5, p. 718, 719, pl. 96, fig. 1; pl. 98, figs. 1-8.

Cushman (1919, p. 55) described *Orthophragmina antillea* from the middle Eocene of St. Bartholomew. Although the type is an uncut specimen (pl. 1, fig. 1), he illustrated several thin sections. Some of these thin sections may represent this species (for example, fig. 4, pl. 4), but others do not as Cole and Gravell (1952, p. 723) have stated.

Several years ago I examined the type specimen and discovered that it is not a single specimen as Cushman apparently assumed. There are several specimens of *Asterocyclina* superimposed on each other in such a manner that a large, many rayed appearance, as shown by the illustration, is produced.

As several species of *Asterocyclina* occur in the Senn material, it is impossible to know which might be *A. antillea.* It might be either *A. penonensis* Cole and Gravell or *A. habanensis* Cole and Bermudez. Thus, at this time, it is impossible to reinstate the name *A. antillea.*

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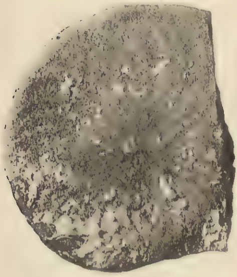
PLATES

EXPLANATION OF PLATE 18

Figure		Page
1, 2, 7-16.	**Operculinoides floridensis** (Heilprin)	182
	External views, x 10.	
	1. Loc. 2, specimen identified as this species. 2, 7-10. Loc. 1, specimens identified as *O. ocalana* of which fig. 9 is the most typical. 11, 12. Loc. 5, specimens identified as *O. vaughani*. 13, 16. Loc. 9, specimens identified as *O. cushmani*. 14, 15. Loc. 8, specimens identified as *O. oliveri*.	
3-6.	**Operculinoides sabinensis** (Cole)	196
	Loc. 11, specimens with and without beaded sutures.	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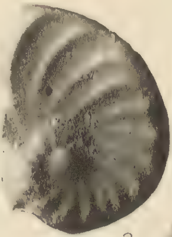
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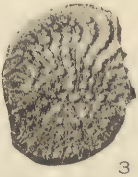
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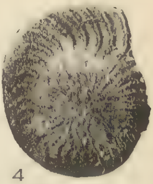
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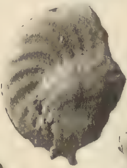
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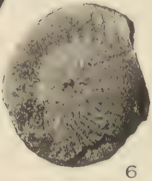
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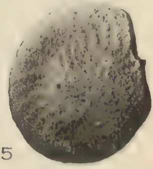
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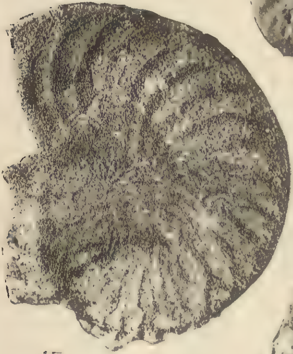
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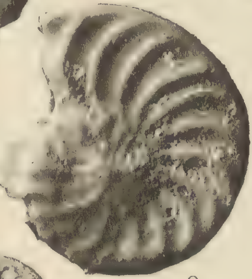
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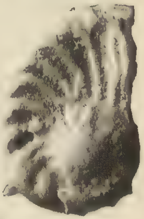
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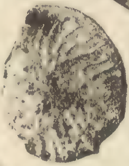
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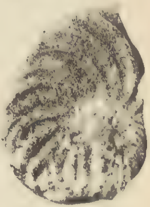
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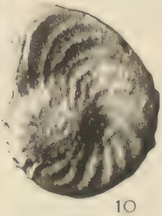
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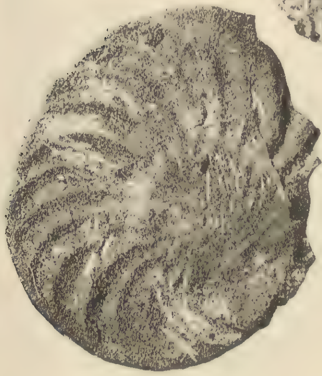
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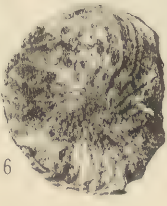
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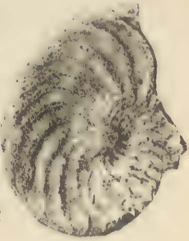
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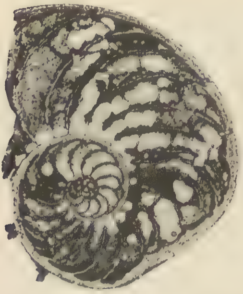
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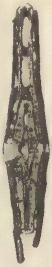
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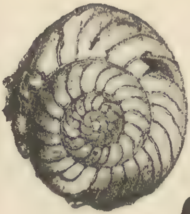
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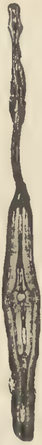
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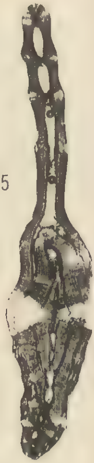
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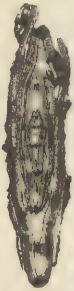
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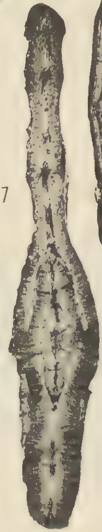
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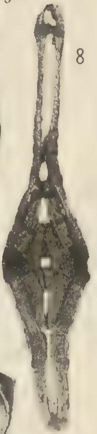
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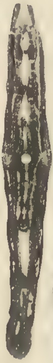
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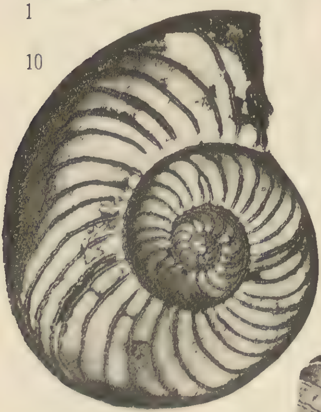
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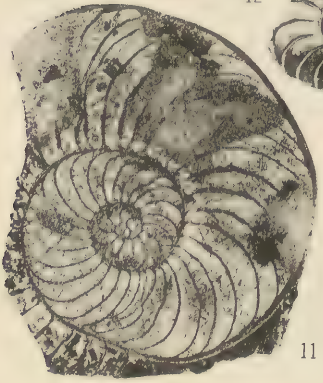
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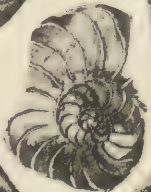
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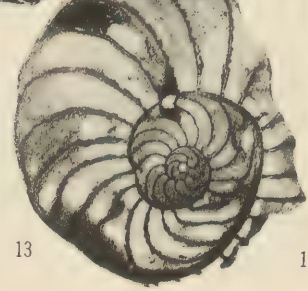
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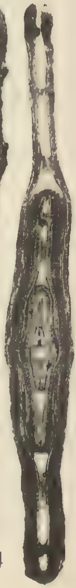
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2, 4, 5, 7-9. Transverse sections, all x 20 except 4, x 12.5. 2. Loc. 7, specimen called *O. cushmani*. 4. Loc. 8, specimen called *O. oliveri*. 5. Loc. 5, specimen called *O. vaughani*. 7. Loc. 13*b*. 8. Loc. 1, specimen called *O. ocalana*. 9. Loc. 9. 14. Loc. 2, specimen called *O. floridensis*.

3, 6. **Operculinoides sabinensis** (Cole) 196

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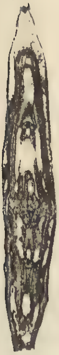
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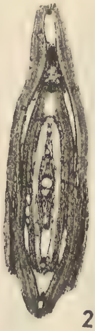
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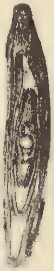
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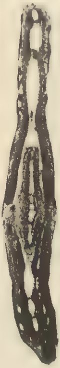
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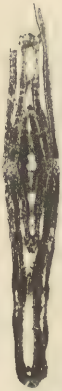
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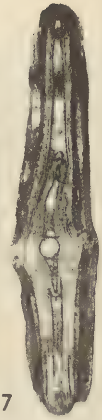
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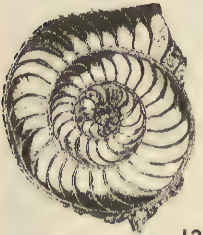
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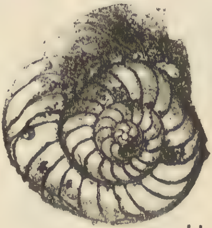
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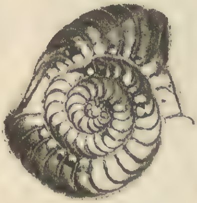
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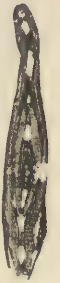
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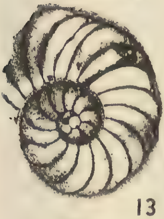
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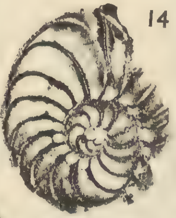
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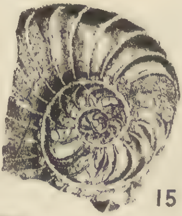
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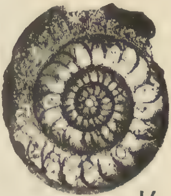
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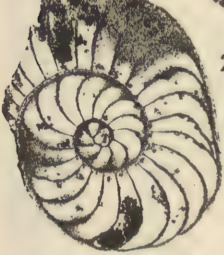
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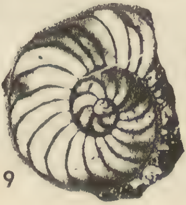
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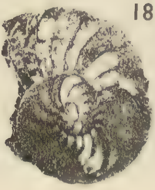
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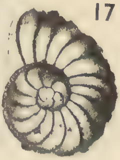
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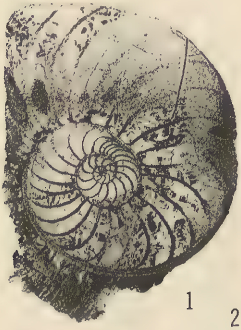
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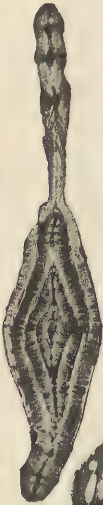
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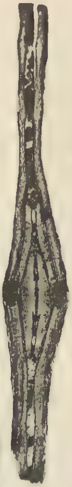
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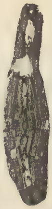
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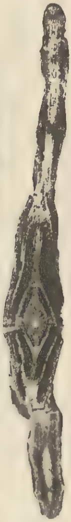
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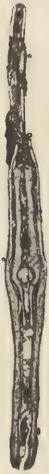
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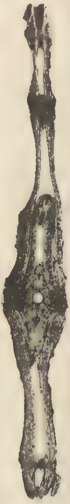
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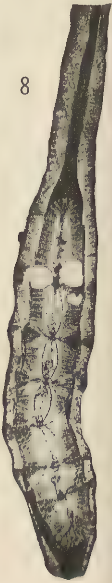
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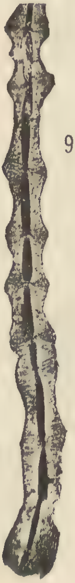
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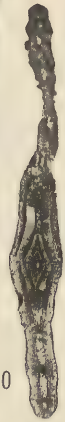
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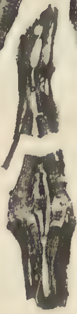
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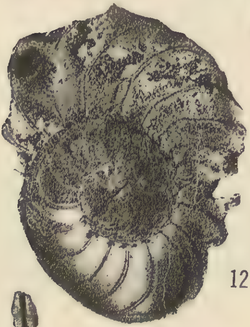
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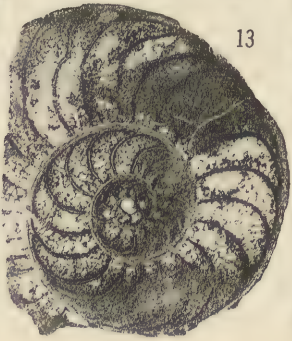
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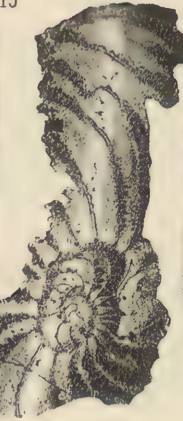
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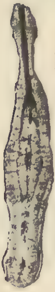
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EXPLANATION OF PLATE 21

Figure		Page
1-15.	**Operculinoides floridensis** (Heilprin)	182

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2-11, 15. Transverse sections, x 20, except 5, 10, x 12.5. 2. Loc. 14, specimen called *O. antillea.* 3. Loc. 8, microspheric specimen called *O. oliveri.* 4. Loc. 7, specimen called *O. bartschi plana.* 5, 10. Loc. 12. 6. Loc. 8, megalospheric specimen called *O. oliveri.* 7. Loc. 1, specimen called *O. ocalana.* 8. Loc. 14, umbonal part of a specimen called *O. antillea.* 9. Loc. 13*a*, peripheral part of a specimen called *O. antillea.* 11. Loc. 7, specimen called *O. cushmani.* 15. Loc. 13*a*, specimen called *O. antillea.*

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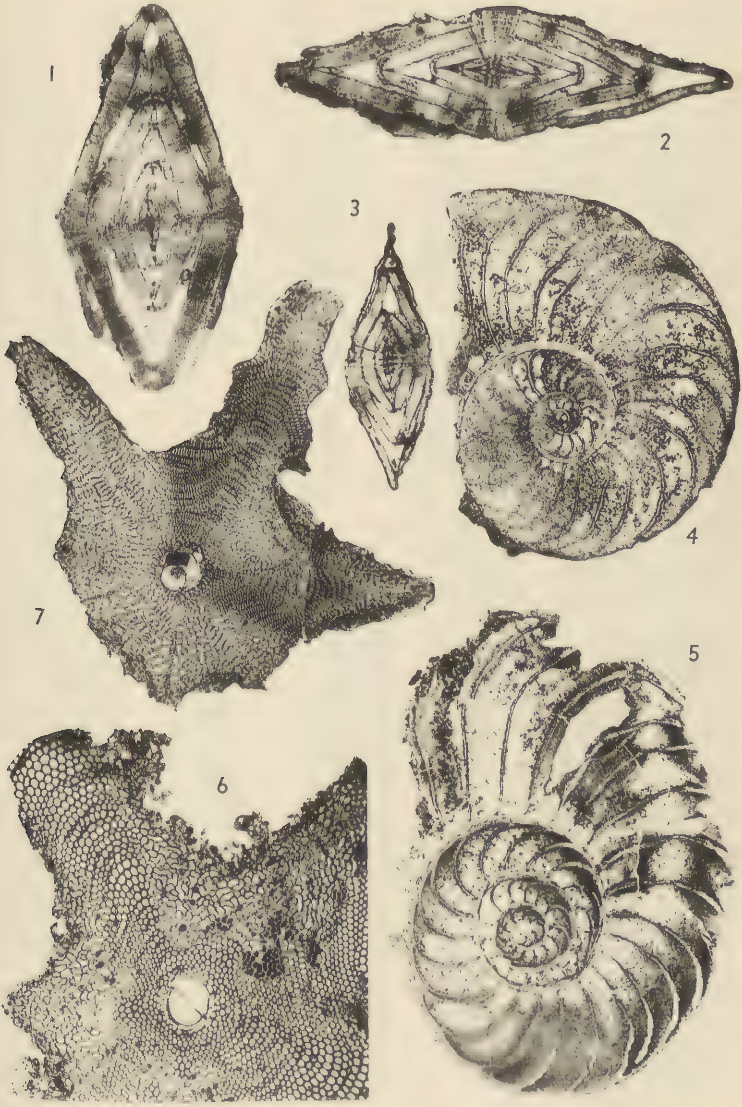
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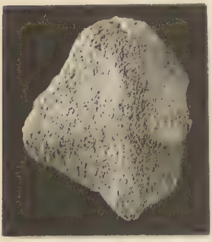
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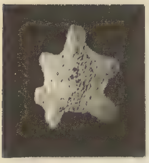
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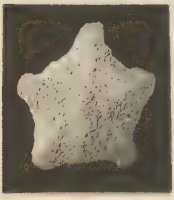
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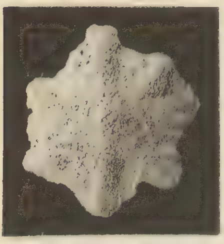
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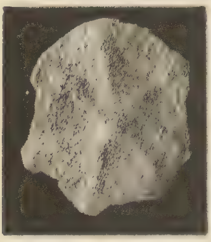
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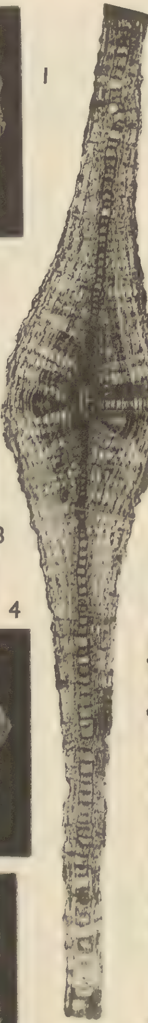
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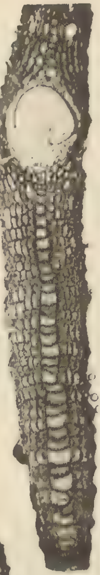
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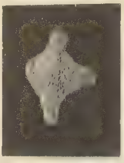
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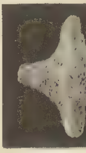
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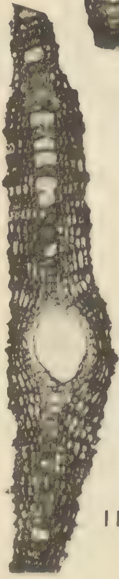
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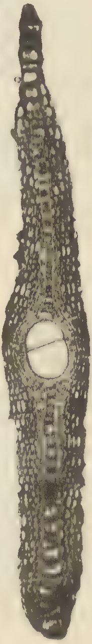
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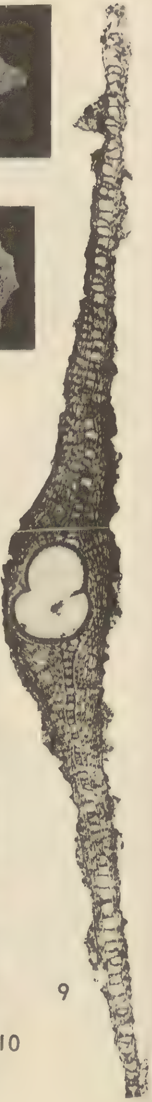
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EXPLANATION OF PLATE 23

Figure		Page
1-12.	**Lepidocyclina (Lepidocyclina) asterodisca** Nuttall	201
	1-7. External views, x 3.5.	
	8-11. Transverse sections, x 20, of megalospheric specimens.	
	12. Transverse section, x 20, of a microspheric specimen.	
	All specimens from loc. 15.	

EXPLANATION OF PLATE 24

Figure Page

1-4. **Heterostegina israelskyi** Gravell and Hanna 202

1, 2. Median sections, x 12.5.

3, 4. Transverse sections; 3, x 20; 4, x 12.5.

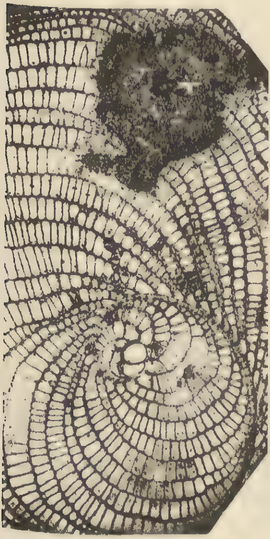
5. **Operculinoides dia** (Cole and Ponton) 198

Median section, x 20.

6, 7. **Lepiodocyclina (Lepidocyclina) asterodisca** Nuttall 201

6. Part of an equatorial section, x 40, of a microspheric individual.

7. Equatorial section, x 12.5, of a megalospheric individual.
All specimens from loc. 15.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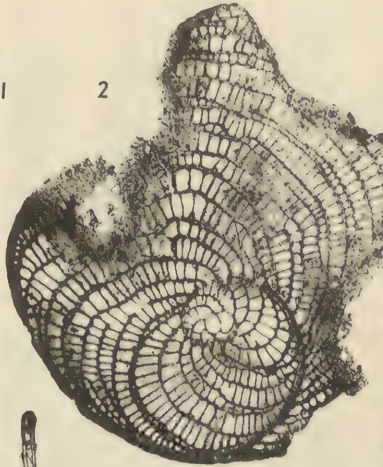
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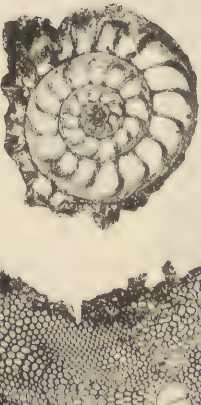
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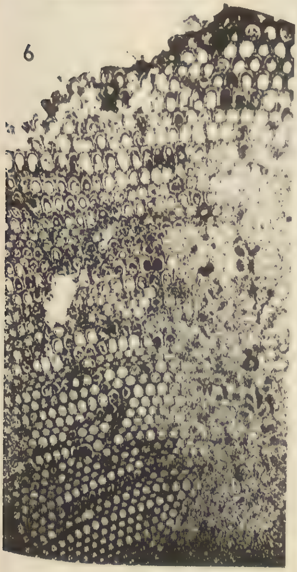
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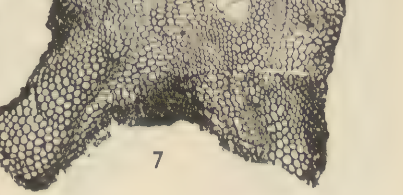
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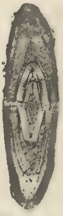
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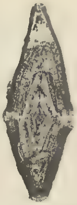
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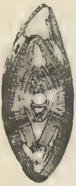
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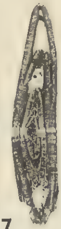
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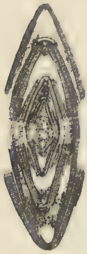
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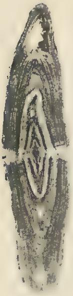
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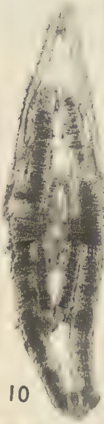
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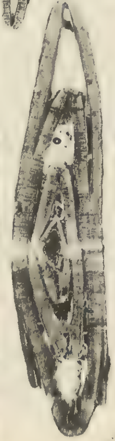
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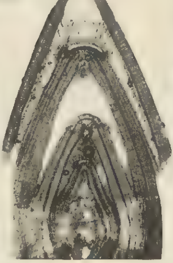
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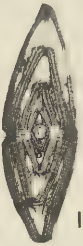
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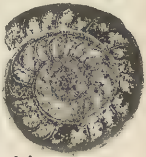
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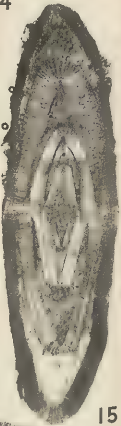
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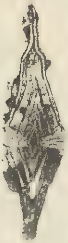
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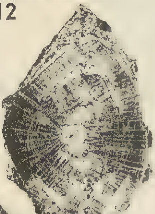
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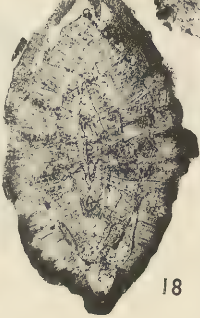
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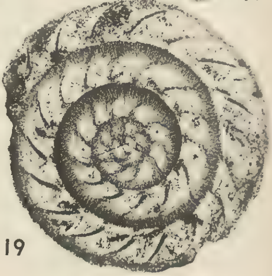
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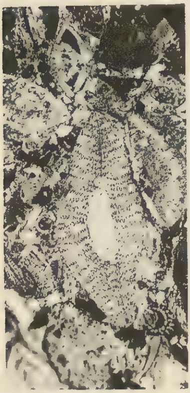
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EXPLANATION OF PLATE 25

Figure	Page

1, 2, 14, 15. **Operculinoides panamensis** (Cushman) 200

1, 2, 15. Transverse sections, 1, 2, x 20; 15, x 40; introduced for comparison with *O. dia*; 15, an enlargement of fig. 1; loc. 17.

14. Median section, x 20; loc. 17.

3-13, 16. **Operculinoides dia** (Cole and Ponton) 198

Transverse section, x 20, except 10-12, x 40.

3, 6-8, 11-13. Specimens called *O. vicksburgensis*; 11, enlargement of fig. 7; 12, enlargement of part of fig. 8 to show apertures; Loc. 4.

4, 10. Specimens called *O dia*; 10, enlargement of fig. 4; loc. 1*a*.

5. Specimen identified as *O. semmesi*; loc. 16.

9. Specimen identified as *O. bullbrooki*; loc. 16.

16. Cuban specimen with a compressed, fragile flange; loc. 15.

17-19. **Amphistegina parvula** (Cushman) 201

17, 18. Transverse sections, x 20, to show numerous radiating pillars; 17, centered; 18, not centered; loc. 13*c*.

19. Median section, x 20; loc. 13*d*.

20. **Asterocyclina penonensis** Cole and Gravell 202

Vertical section, x 20; loc. 13*b*.

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LARGER FORAMINIFERA FROM CARRIACOU BRITISH WEST INDIES

By

W. Storrs Cole
Cornell University, Ithaca, N. Y.

April 18, 1958

Paleontological Research Institution
Ithaca, New York, U. S. A.

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LARGER FORAMINIFERA FROM CARRIACOU, BRITISH WEST INDIES*

W. Storrs Cole
Cornell University, Ithaca, New York

ABSTRACT

The occurrence of larger Foraminifera in 14 samples from the island of Carriacou, British West Indies, is discussed, and critical species are illustrated. One sample had an upper Eocene fauna, five had upper Oligocene species and eight had species which are seemingly of Miocene age. Correlations with other areas are suggested. Names of and variation in *Operculinoides cojimarensis* (D. K. Palmer) are discussed. This species is illustrated by specimens from Carriacou and elsewhere.

INTRODUCTION

Last year (1957) Mr. P. H. Martin-Kaye, government geologist of the Windward Islands, British West Indies, sent me 14 samples of fossiliferous limestone collected on the island of Carriacou. The Island is the largest of the Grenadines, a group of some 600 small islands within the Windward Islands. One of the samples had an upper Eocene fauna of larger Foraminifera, five had upper Oligocene species and eight had species which are seemingly of Miocene age.

Trechmann (1935, p. 533) in a brief account of the geology of Carriacou noted the presence of *Amphistegina* and a "few Lepidocyclinae" near the base of the Carriacou limestone of Kendeace Point. He stated (p. 535), moreover, that H. Nageli recognized that "the microfauna of the orbitoidal marl and of the pteropod marl, which both lie close together and not far below the Carriacou Limestone series" is Oligocene, but the Carriacou limestone is probably Miocene.

The localities from which the samples were collected follow:

EOCENE

Locality 4064.—Near Hillsborough Rectory.

OLIGOCENE

4206.—North end of Windward village.
4207.—One-fourth mile north of Windward village.
4214.—Loose blocks, one-fourth mile north of Bogles.
4120.—Meldrum.
4223.—Limlair (Baie a l'Eau).

MIOCENE

4050.—Near summit of Top Hill road.
4071.—Top Hill road, one-half mile south of Belair.
4090.—Coast, north side of Kendeace Point.
4145 and 4146.—Dumfries, Mount Royal road.

---

*The cost of the printed plates was supplied by the William F. E. Gurley Foundation for paleontology of Cornell University.

4199 and 4202.—North side of Point St. Helaire.

4227.—Belvidere road, one-third mile from Windward.

Through the courtesy of Dr. C. W. Merriam of the U. S. Geological Survey thin sections of the limestone were prepared. These thin sections will be deposited in the U. S. National Museum.

FAUNAS AND CORRELATION

EOCENE

The one sample (loc. 4064) with Eocene larger Foraminifera contained the following species:

Asterocyclina minima (Cushman)—rare
Heterostegina ocalana Cushman—rare
Lepidocyclina (*Pliolepidina*) *macdonaldi* Cushman—rare
  pustulosa H. Douvillé—rare
  pustulosa tobleri H. Douvillé—abundant

Cushman (1918, p. 94, 96) recorded megalospheric specimens which he named *Lepidocyclina panamensis* (= *L.* (*P.*) *pustulosa tobleri*) and microspheric specimens of this same species which he called *Lepidocyclina duplicata* (= *L.* (*P.*) *pustulosa tobleri*) from U. S. G. S. sta. 6586*e* from near the mouth of the Tonosi River, Panama. His illustration (pl. 39, fig. 6) of a part of a thin section from this locality is identical with parts of thin sections from Carriacou (loc. 4064).

Although the abundance of specimens of *L.* (*P.*) *pustulosa tobleri* corresponds to that of the Tonosi River locality in Panama, the association of species is the same as that found in the Gatuncillo formation of the Panama Canal Zone and vicinity (Cole, 1952, p. 4).

OLIGOCENE

The distribution of the nine recognizable species in the five samples from the Oligocene is shown in the table.

The association of species in these samples is the same as that found in samples from the upper part of the Caimito formation of Panama (Cole, 1957*a*, p. 315). This part of the Caimito formation is placed in the *L.* (*Lepidocyclina*)—*L.* (*Eulepidina*) zone (Cole, 1957*b*, p. 35). Although *L.* (*Eulepidina*) was not found in the samples, *L.* (*Nephrolepidina*) *vaughani*, another species which seemingly is characteristic of the upper part of this zone, was present in abundance. Moreover, the upper part of the *L.* (*Lepidocyclina*)—*L.* (*Eulepidina*) zone contains abundant *Miogypsina.*

OLIGOCENE SPECIES

Locality number	4120	4206	4207	4214	4223
Heterostegina antillea Cushman	c	r	c	r	
Lepidocyclina (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé	r	r		r	
giraudi R. Douvillé	r	r		r	
waylandvaughani Cole		r		r	
(*Nephrolepidina*) *vaughani* Cushman	r	a	r		a
tournoueri Lemoine and R. Douvillé			r	r	
Miogypsina (*Miogypsina*) *antillea* (Cushman)	c			c	
Miogypsina (*Miolepidocyclina*) *panamensis* (Cushman)		c	c	c	r
Operculinoides dia (Cole and Ponton)		r			r

a = abundant; c = common; r = rare

MIOCENE

Samples (locs. 4050, 4071, 4090, 4145, 4146, 4199, 4202 and 4227) representing the Carriacou limestone contained an *Amphistegina* sp. and *Operculinoides cojimarensis* (D. K. Palmer). In addition, two samples (locs. 4145 and 4146) contained rare specimens of *Miogypsina* (*Miolepidocyclina*) *staufferi* Koch, and two samples (locs. 4146 and 4202) had rare specimens of *Coskinolina floridana* Cole.

Samples from four localities (locs. 4071, 4199, 4202 and 4227) contained abundant *Amphistegina* sp., probably species of *Asterigerina*, and rare specimens of *Operculinoides cojimarensis*, whereas the samples from the other four localities (locs. 4050, 4090, 4145, 4146) had abundant *O. cojimarensis*, and the amphistegines were relatively infrequent.

O. cojimarensis was known only from the Cojimar formation of Cuba. However, this study demonstrates that *O. tuxpanensis* (Thalmann) and *O. tamanensis* Vaughan and Cole are synonyms of *O. cojimarensis.*

Mrs. D. K. Palmer (1934, p. 260) stated that *O. cojimarensis* occurs commonly at the type locality of the Cojimar formation. Bermudez (1950, p. 277), following Mrs. Palmer, assigned this formation to the upper Oligocene. He listed among other species of smaller Foraminifera, *Siphogenerina transversa* Cushman and *S. lamellata* Cushman. He considerered that *S. transversa* characterized the lower faunal zone of the Cojimar formation and *S. lamellata* marked the middle zone.

S. transversa was described from specimens from the La Boca marine member of the Panama formation. Woodring (1957, p. 42) assigned the Panama formation to the early Miocene. *S. lamellata* was described from Choctawhatchee marl near Red Bay, Florida. The Choctawhatchee formation is assigned to the middle and upper Miocene (Cooke *et al.*, 1943).

Thalmann (1935) and Barker (1939, p. 312) reported specimens called *O. tuxpanensis* from the Miocene of Mexico. Vaughan and Cole (1941, p. 46) reported this species from the Miocene of Trinidad, and Cole (1938, p. 18) recovered this species in association with *Siphogenerina lamellata* from a sample from a well in Florida in the Choctawhatchee formation. Vaughan and Cole (1941, p. 44) reported specimens called *O. tamanensis* from the Miocene of Trinidad.

Inasmuch as *O. tuxpanensis* and *O. tamanensis* are considered to be synonyms of *O. cojimarensis* and as the associated species of *Siphogenerina* are known to occur in the Miocene, the Cojimar formation is believed to be Miocene in age.

The Carriacou limestone on foraminiferal evidence would correlate roughly with the Cojimar formation of Cuba, the Tuxpan formation of the Tampico Embayment area, Mexico, and the Brasso clay formation of Trinidad.

The infrequent specimens of *Coskinolina floridana* are thought to be reworked from the Eocene. The rare specimens, represented only by three vertical sections, of a *Miogypsina* identified as *M.* (*Miolepidocyclina*) *staufferi* Koch could be either reworked or indigenous.

Cole (1957*a*, p. 325) stated recently that *M.* (*M.*) *staufferi* probably occurs in the La Boca marine member of the Panama formation. He noted also (p. 325) that *M.* (*M.*) *staufferi* occurs in Florida at a higher stratigraphic level than does *M.* (*M.*) *panamensis.*

Inasmuch as *M.* (*M.*) *panamensis* occurs on Carriacou Island in samples with Oligocene *Lepidocyclina*, the stratigraphic distribution of these two species of *Miogypsina* are seemingly the same as in Florida and Panama.

The Carriacou limestone seemingly should be placed in the upper part of the *L.* (*Lepidocyclina*)—*Miogypsina* zone (Cole, 1957*b*, p. 35, 37). The upper part of this zone from the data at hand has *Miogypsina* present, but *L.* (*Lepidocyclina*) has disappeared.

SPECIES WHICH ARE ILLUSTRATED

The following critical species are illustrated but are not discussed as these species are so well known that additional comments are not needed. As it was impossible to separate specimens from the matrix, all the illustrations are from thin sections made at random through the sample of limestone. Therefore, it was impossible in many cases to obtain correctly oriented thin sections.

For each species listed there is a citation to a published figure which most nearly resembles the specimens from Carriacou.

EOCENE SPECIES

Lepidocyclina (*Pliolepidina*) *macdonaldi* Cushman	Pl. 26, fig. 3
See: Cushman, 1918, pl. 40, figs. 2-5.	
Lepidocyclina (*Pliolepidina*) *pustulosa* H. Douvillé	Pl. 26, fig. 4
See: Cole, 1952, pl. 13, fig. 18.	
Lepidocyclina (*Pliolepidina*) *pustulosa tobleri* H. Douvillé	
Megalospheric specimen	Pl. 26, fig. 6
See: Cole, 1952, pl. 13, fig. 21.	
Microspheric specimen	Pl. 26, figs. 5, 6
See: Cushman, 1918, pl. 41, figs. 3, 4.	

OLIGOCENE SPECIES

Heterostegina antillea Cushman .... Pl. 26, fig. 11
See: Cole, 1957*a*, pl. 25, fig. 4.

Lepidocyclina (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé .... Pl. 26, fig. 12
See: Cole, 1952, pl. 16, figs. 10, 12.

Lepidocyclina (*Lepidocyclina*) *giraudi* R. Douvillé .... Pl. 26, fig. 10; Pl. 28, fig. 4
See: Cole, 1945, pl. 7, figs. 2-13.

Lepidocyclina (*Lepidocyclina*) *waylandvaughani* Cole .... Pl. 27, fig. 4; Pl. 28, figs. 2, 3
See: Cole, 1957*b*, pl. 4, figs. 2, 5.

Lepidocyclina (*Nephrolepidina*) *tournoueri* Lemoine and R. Douvillé .... Pl. 28, fig. 8
See: Cole, 1952, pl. 19, fig. 10.

Lepidocyclina (*Nephrolepidina*) *vaughani* Cushman .... Pl. 26, fig. 12; Pl. 27, figs. 5, 6
See: Cole, 1952, pl. 21.

Miogypsina (*Miogypsina*) *antillea* (Cushman) .... Pl. 26, fig. 2
See: Cole, 1957*a*, pl. 26, figs. 6, 7.

Miogypsina (*Miolepidocyclina*) *panamensis* (Cushman) .... Pl. 26, fig. 9; Pl. 27, figs. 1-3
See: Cole, 1957*a*, pl. 26, fig. 5; pl. 27, figs. 2-8.

MIOCENE SPECIES

Miogypsina (*Miolepidocyclina*) *staufferi* Koch .... Pl. 26, figs. 7, 8
See: Koch, 1926, pl. 28, fig. 2.

Coskinolina floridana Cole (reworked Eocene specimen) .... Pl. 26, fig. 1
See: Cole, 1941, pl. 5, figs. 4, 5.

DESCRIPTION OF SPECIES

Operculinoides cojimarensis (D. K. Palmer) Pl. 28, figs. 1, 5-7; Pl. 29

1934. *Operculinella cojimarensis* D. K. Palmer, Mem. Soc. Cubana Hist. Nat., v. 8, No. 4, p. 259, 260, pl. 15, figs. 1, 3, 4, text fig. 18.

1935. *Operculina tuxpanensis* Thalmann, Eclogae geol. Helvet., v. 28, p. 603-605, text figs. *a, b*.

1936. *Operculinoides tuxpanicus* Vaughan and Cole, U. S. Nat. Mus., Proc., v. 83, No. 2996, p. 494, pl. 37, figs. 4-9.

1938. *Operculinoides tuxpanensis* (Thalmann), Cole, Florida Geol. Sur., Bull. 16, p. 38, 39, pl. 5, figs. 14-17.

1939. *Operculinoides tuxpanensis* (Thalmann), Barker, U. S. Nat. Mus., Proc., v. 86, No. 3052, p. 311, 312, pl. 16, fig. 2; pl. 17, fig. 2.

1941. *Operculinoides tamanensis* Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 43, 44, pl. 10, figs. 9, 10; pl. 11, figs. 8-10; pl. 12, figs. 1-3.

1941. *Operculinoides tuxpanensis* (Thalmann), Vaughan and Cole, *idem*, p. 45, 46, pl. 14, figs. 1-4.

The specimens from Carriacou were identified first as *O. cojimarensis* because of the inflated tests with thick revolving walls and the curvature of the sutures. However, certain specimens (fig. 8, Pl. 29) resembled *O. tuxpanensis* as these specimens were small and compressed. Other specimens (fig. 10, Pl. 29) resembled specimens of *O. tamanensis* although they had slightly thicker revolving walls.

Therefore, several thin sections were prepared from topotype specimens of *O. tamanensis* and *O. cojimarensis.* There were abundant specimens of *O. tamanensis,* but only four specimens of *O. cojimarensis,* which had been sent to the writer by the late Mrs. D. K. Palmer, were available. A transverse section (fig. 5, Pl. 29) made from one of these is illustrated.

The type transverse section (D. K. Palmer, 1934, pl. 15, fig. 4) was made from a specimen with an approximate height of 3.9 mm., a thickness through the center of about 1.5 mm. and with well-developed umbonal plugs. A transverse section of a topotype with the same shape has a height of 3.1 mm., a thickness through the center of 1.1 mm., and umbonal plugs with a surface diameter of 250 μ. The transverse section (fig. 5, Pl. 29) of another topotype has a height of 5.1 mm., a thickness through the center of 1.2 mm., and umbonal plugs with a surface diameter of 500 μ. This specimen is larger than the type, is more compressed umbonally, and has a wider flange.

The Carriacou specimen (fig. 7, Pl. 29), which resembles the type transverse section, has a height of 3.65 mm., a thickness through the center of 1.07 mm., and umbonal plugs with a surface diameter of 200 μ.

The type median section (Palmer, 1934, pl. 15, fig. 1) should be compared with the median section of *O. tamanensis* (fig. 16, Pl. 29), and the illustration (fig. 13, Pl. 29) of the sutural pattern of a specimen from Carriacou should be compared with the external view of *O. cojimarensis* (Palmer, 1934, pl. 15, fig. 3). The similarity between these specimens will be apparent.

Measurements of topotypes of *O. tamanensis* follow on page 226.

The compressed specimen (fig. 8, Pl. 29) from Carriacou at first assigned to *O. tuxpanensis* has a height of 2.0 mm., a thickness through the center of 0.4 mm., and umbonal plugs with a surface diameter of 70 μ. The measurements of this specimen are nearly identical with those of the specimen (fig. 1, Pl. 29) from Trinidad.

The specimen from Trinidad (fig. 1, Pl. 29) is one end of a series (*O. tuxpanensis*), the other end of which is represented by larger, more inflated specimens (*O. tamanensis*). In a similar manner the compressed specimen from Carriacou (*O. tuxpanensis*) is one end of a series, the other end of which is represented by large, strongly inflated specimens (*O. cojimarensis*).

As the same gradation occurs in the median sections, these three species are combined.

O. TAMANENSIS VAUGHAN AND COLE

Median Sections

Locality	Trinidad		
Specimen	Pl. 29, fig. 15	Pl. 29, fig. 14	Pl. 29, fig. 16
Height mm.	2.0	2.85	3.7
Width mm.	1.65	2.3	3.7
Embryonic chambers: Diameters of initial chamber μ	——	80x90	70x80
Diameters of initial chamber μ	——	50x80	45x70
Distance across both chambers μ	150	150	125
Coils	3	4	4½
Chambers in first volution	9	8	7
Chambers in final volution	21	27	29
Total number of chambers	43	72	90

Transverse sections

Locality	Trinidad			
Specimen	Pl. 29, fig. 1	Pl. 29, fig. 2	Pl. 29, fig. 3	Pl. 29, fig. 4
Height mm.	2.4	2.4	3.05	3.38
Thickness at center mm.	0.4	0.52	0.61	0.67
Diameter of umbonal plug μ	100	110	160	210
Embryonic chambers: Distance across both chambers μ	120	100	125	100
Height μ	65	65	70	80

Ecological implications.—Cole (1958, p. 191) demonstrated recently that in the formation of the test in specimens of *O. antillea* (Cushman) there was environmental influence with the thinner walled, less robust tests developed in situations where clastic sediments were accumulated, whereas more robust tests were produced in situations where limestones were formed.

Thus, the specimens of *O. cojimarensis* from Trinidad, Mexico, and Florida developed in an environment which favored the formation of relatively thin-walled tests, whereas the specimens from Carriacou produced thick-walled tests.

The same conditions were reported recently by Sachs (1957) for the species, *O. bermudezi.* He was able to demonstrate that thin-walled specimens (*O. georgianus*) merged into thick-walled lenticular specimens (*O. antillea*) although at that time the ecological implications were not appreciated fully either by Sachs or the writer.

Comments.—In the Carribbean region there are seemingly in the upper Oligocene two recognizable species of *Operculinoides,* namely, *O. dia* (Cole and Ponton) and *O. panamensis* (Cushman) (Cole, 1958, p. 198, 200). Unless other species are found eventually, there is only one species of *Operculinoides* present in the Miocene.

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PLATES

EXPLANATION OF PLATE 26

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4.	**Lepidocyclina (Pliolepidina) pustulosa** H. Douvillé Vertical section, x 40, of a specimen of the kind called *L.* (*P.*) *subglobosa* Nuttall; loc. 4064.	223
5, 6.	**Lepidocyclina (Pliolepidina) pustulosa tobleri** H. Douvillé 5. Part of a vertical section, x 20, of a microspheric specimen of the kind called *L. duplicata* Cushman to show the subdivision of the equatorial layer at its distal end; loc. 4064. 6. Vertical section, x 20, of a megalospheric individual with a part of a vertical section, upper right, of a microspheric individual; this kind of a megalospheric individual called *L. panamensis* Cushman; loc. 4064.	223
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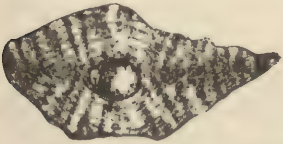
9.	**Miogypsina (Miolepidocyclina) panamensis** (Cushman) Vertical section, x 40, which shows the subapically situated embryonic apparatus; loc. 4206.	224
10.	**Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé Oblique section, x 20, to show embryonic chambers, equatorial chambers, and part of the lateral chambers; loc. 4214.	224
11.	**Heterostegina antillea** Cushman Part of a transverse section, x 20; loc. 4207.	224
12.	**Lepidocyclina (Nephrolepidina) vaughani** Cushman Vertical section, x 12.5, to which is attached, upper left, a part of vertical section of *L.* (*Lepidocyclina*) *canellei* Lemoine and R. Douvillé; loc. 4120.	224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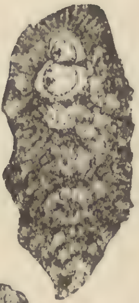
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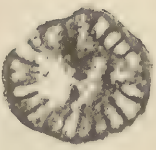
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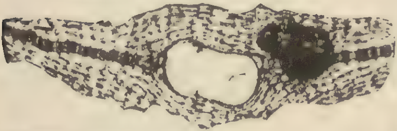
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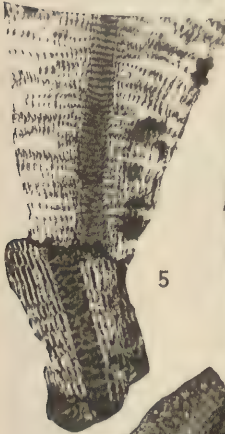
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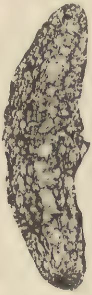
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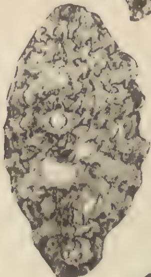
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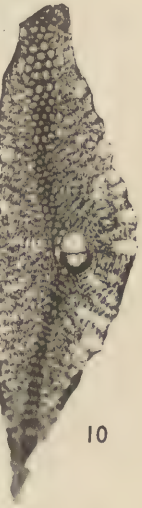
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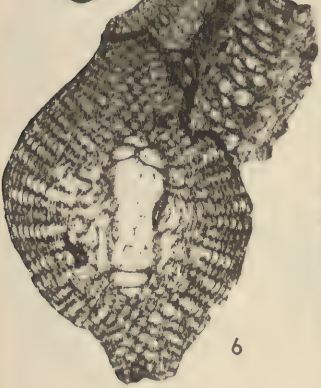
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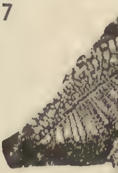
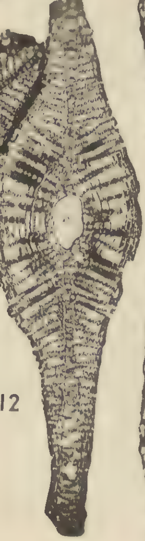
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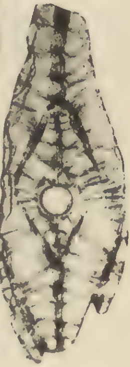
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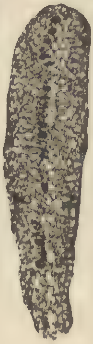
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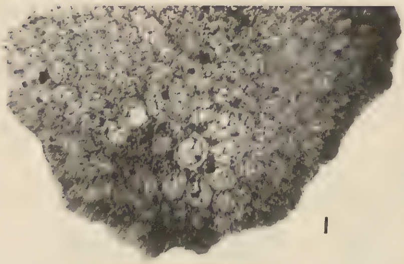
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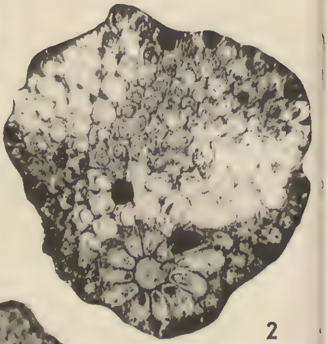
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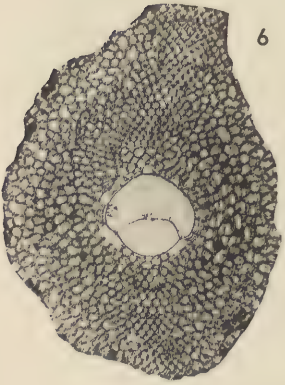
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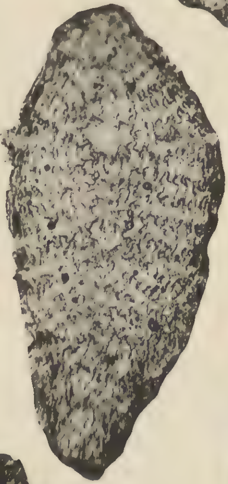
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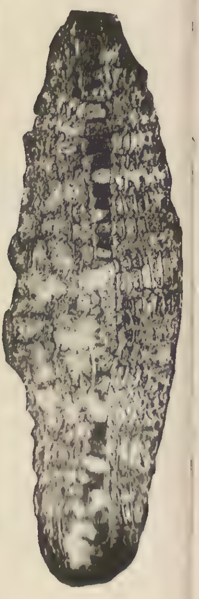
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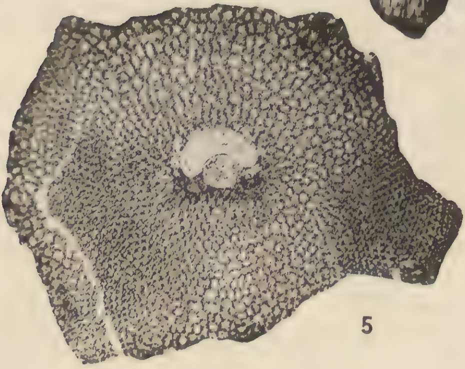
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EXPLANATION OF PLATE 27

Figure Page

1-3. **Miogypsina (Miolepidocyclina) panamensis** (Cushman) 224

1. Part of an equatorial section, x 40, to show the subcentrally located embryonic chambers and the coil of periembryonic chambers; loc. 4206.

2. Equatorial section, x 40, which is thought to represent the microspheric form of this species; loc. 4206.
3. Vertical section, x 40; loc. 4214.

4. **Lepidocyclina (Lepidocyclina) waylandvaughani** Cole................... 224

Vertical section, x 40, not centered, to show the equatorial layer and lateral chamber; loc. 4214.

5, 6. **Lepidocyclina (Nephrolepidina) vaughani** Cushman....................... 224

Equatorial sections, x 20; 5, loc. 4223; 6, loc. 4206.

EXPLANATION OF PLATE 28

Figure Page

1, 5-7. **Operculinoides cojimarensis** (D. K. Palmer) 224

1. Part of the transverse section illustrated as fig. 3, Plate 29, x 40, to illustrate the marginal cord, an aperture and the umbonal plugs; Guaico-Tamana Road, ravine east of mile 13½, Trinidad, B. W. I.

5. Part of the median section illustrated as fig. 16, Plate 29, x 20; same loc. as fig. 1.

6. Median section, x 12.5; same loc. as fig. 1.

7. Part of a median section, x 40; same loc. as fig. 1.

2, 3. **Lepidocyclina (Lepidocyclina) waylandvaughani** Cole.................. 224

2. Part of the vertical section illustrated as fig. 3, x 40.

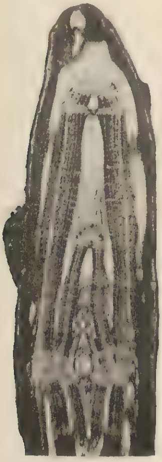
3. Vertical section, x 20; loc. 4206.

4. **Lepidocyclina (Lepidocyclina) giraudi** R. Douvillé........................ 224

Vertical section, x 40, of a small individual; loc. 4206.

8. **Lepidocyclina (Nephrolepidina) tournoueri** Lem. and R. Douv. 224

Part of an oblique equatorial section, x 40, to show the elongate hexagonal equatorial chambers and the large, open lateral chambers; loc. 4207.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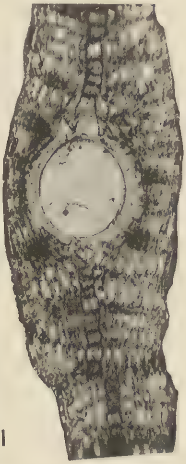
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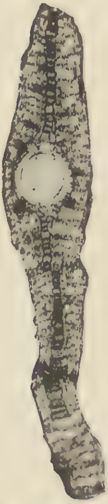
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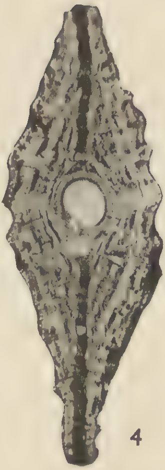
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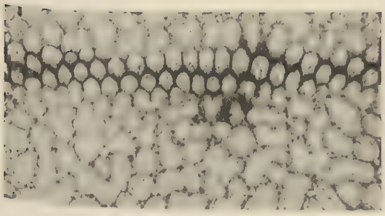
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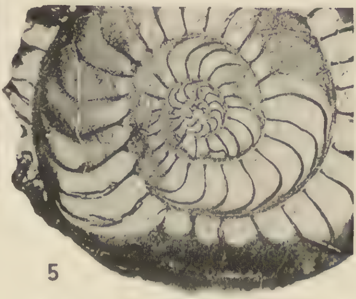
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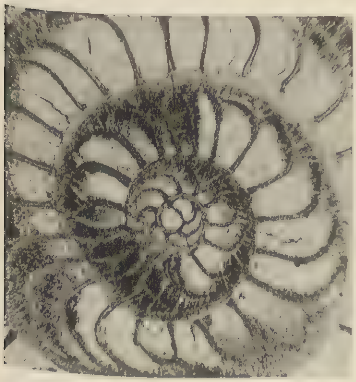
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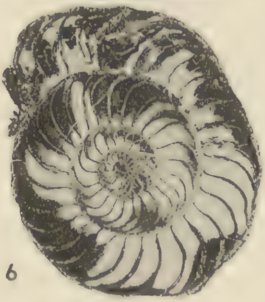
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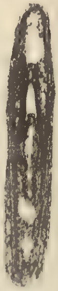
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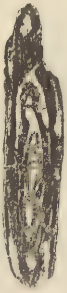
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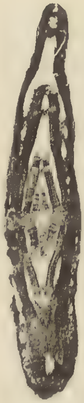
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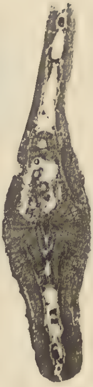
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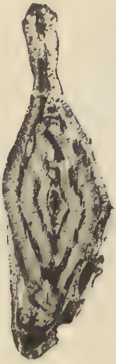
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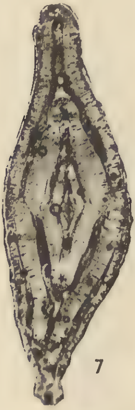
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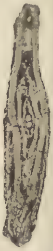
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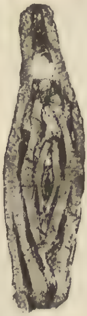
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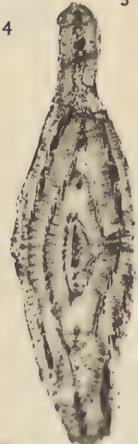
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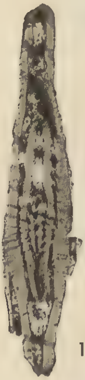
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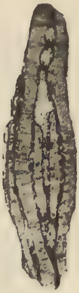
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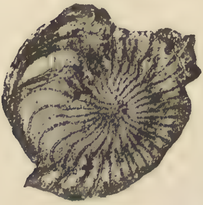
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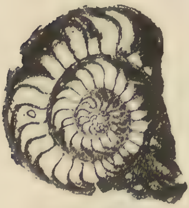
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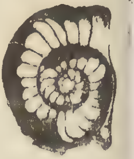
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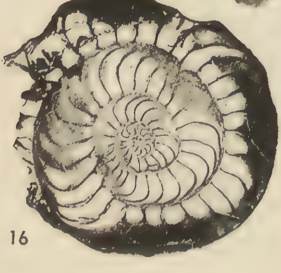
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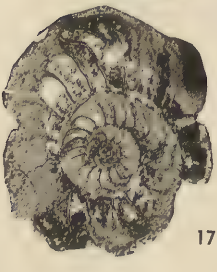
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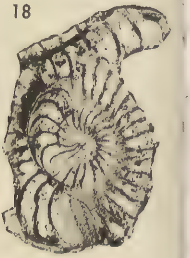
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EXPLANATION OF PLATE 29

Figure Page

1-18. **Operculinoides cojimarensis** (D. K. Palmer) 224

Sequence of transverse and median sections to illustrate the gradation from *O. tuxpanensis* (Thalmann) through *O. tamanensis* Vaughan and Cole to *O. cojimarensis* (D. K. Palmer).

1-12. Transverse sections, x 20.

1, 8. Specimen similar to *O. tuxpanensis* (Thalmann).

4. Topotype similar to types of *O. tamanensis* Vaughan and Cole.

5. Topotype of *O. cojimarensis* (D. K. Palmer).

7. Carriacou specimen which should be compared with the type illustration (D. K. Palmer, 1934, pl. 15, fig. 4).

13-18. Median sections; 13-16, 18, x 12.5; 17, x 20.

13. Section parallel to, but above median plane to illustrate sutural pattern; compare with fig. 3, pl. 15, D. K. Palmer, 1934.

15. Specimen similar to *O. tuxpanensis* (Thalmann).

16. Topotype similar to types of *O. tamanensis* Vaughan and Cole.

1-4, 14-16. Guaico-Tamana Road, ravine east of mile 13½, Trinidad, B. W. I.

5. Two kilometers south-west of Cojimar on the Hershey railroad, Habana Province, Cuba.

6-13, 17, 18. Carriacou, B. W. I. 6, 8, 9, 11, 12, 17, 18, loc. 4145; 7, loc. 4050; 10, 13, loc. 4146.

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NEW MOLLUSKS FROM TROPICAL WEST AMERICA

By

A. Myra Keen
Stanford University, California

May 23, 1958

Paleontological Research Institution
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NEW MOLLUSKS FROM TROPICAL WEST AMERICA

A. Myra Keen
Stanford University, California

ABSTRACT

Six homonymous names are cited, of which four are replaced. One new subgenus of *Chione* is named—*Chionista*—and a type species is formally selected for *Crucibulum*. In addition, four new species are described, one representing a genus—*Leptomya*—not previously recorded in the Eastern Pacific.

INTRODUCTION

During the preparation of a handbook on tropical West American marine mollusks, it was perhaps inevitable that I should find a few homonyms, but I did not expect so many as six. The type specimens of all six species had been in the British Museum (Nat. Hist.) a safe enough repository,—but one not accessible to American workers, who, by their proximity to the Panamic province should have something of a vested interest in the fauna. Therefore, the opportunity has been taken here, insofar as possible, to select new type specimens by treating the replacements not as mere new names but as new species. The new type specimens are deposited in museums that may be visited without the necessity of a trip abroad.

As satisfactory coverage of taxonomic problems cannot well be given in the cramped confines of a semi-popular handbook—such as the one in press—separate publication of the new descriptions is made here in advance of the book. Descriptions of four new species from the Panamic marine province, the selection of a type species for one genus, and the proposal of a new subgenus are also included.

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA

Family **NUCULANIDAE**

Genus **Nuculana** Link, 1807

Beschreib. Nat.-Samml. Rostock, Abt. 3, p. 155. Type species (monotypy), "*Arca rostrata* Chemnitz" [non-binomial] = *A. pernula* Müller, 1779.

Nuculana excavata (Hinds, 1843)

Nucula excavata Hinds, Proc. Zool. Soc. London for 1843, p. 100 [not *N. excavata* Goldfuss, 1837]. Type locality, Panama, in 30 fathoms.

Hinds' type specimen could not be located at the British Museum (Nat. Hist.) upon recent search, but the curator of the molluscan collection, Mr. I. C. J. Galbraith, is unwilling (letter dated Nov. 22, 1957) to consider it lost. There seems no point in renaming this homonym until the type or good replacement material comes to light. The species has not been reported since its original discovery.

Subgenus **Saccella** Woodring, 1925

Carnegie Inst. Washington, Publ. 366. p. 15. Type species (original designation), "*Arca fragilis* Chemnitz" [non-binomial] = *Lembulus deltoideus* Risso, 1826.

Nuculana (Saccella) fastigata Keen, n. sp. Pl. 31, figs. 1, 2

Nucula gibbosa Sowerby, 1833, Proc. Zool. Soc. London for 1832, p. 198 [not *N. gibbosa* Fleming, 1828]. Type locality, Tumbez, Peru.

Nuculana (*Saccella*) *gibbosa* (Sowerby), Hertlein and Strong, 1940, Zoologica, vol. 26, pt. 4, p. 395, pl. 2, figs. 5, 8. Gulf of Nicoya, Costa Rica.

Description.—Shell thick, elongate, posteriorly sharply pointed, white under a greenish periostracum, sculptured with strong concentric and somewhat upturned ribs, the interspaces being smooth-bottomed grooves. Hinge with about 30 teeth in the anterior series, 25 in the posterior series.

Dimensions.—Holotype, length, 36.8 mm., height, 18.9 mm.; convexity, one valve, 8.2 mm.

Type locality.—Off Ballenas Bay, Gulf of Nicoya, Costa Rica, dredged in 35 fathoms (64 meters), lat. 9° 44′ 52″ — 9° 42′ N., long. 84° 51′ 25″ —84° 56′ W.

Repository.—California Academy of Sciences Paleontological Type Collection, No. 9149.

Discussion.—The species ranges from Acapulco, Mexico, to Tumbez, Peru, and is not an uncommon one in the offshore fauna. In addition to other specimens in the California Academy of Sciences collection, the species is represented in West Coast collections by two specimens at Stanford University dredged in Panama Bay; one of these, received from the U. S. National Museum, was dredged by the Albatross Expedition in 47 fathoms. They formed part of U. S. Nat. Mus. lot No. 212, 519.

The specific name is a Latin adjective meaning "sloping up to a point," in reference to the shape of the posterior end of the valves.

Genus **Adrana** H. and A. Adams, 1858

Gen. Rec. Shells, vol. 2, p. 547. Type (subsequent selection, Stoliczka, 1871) *Nucula lanceolata* Lamarck, 1819.

Adrana cultrata Keen, n. sp.

Nucula elongata Sowerby, 1833, Proc. Zool. Soc. London for 1832, p. 197 [not *N. elongata* Bosc, 1801, or Defrance, 1825]. Type locality, Xipixapi, Ecuador.

Adrana elongata (Sowerby), Hertlein and Strong, 1940, Zoologica, vol. 26, pt. 4, p. 409, pl. 2, fig. 16. Champerico, Guatemala.

Description.—Shell white, elongate, the dorsal margin nearly straight, the ventral margin smoothly arched and nearly symmetrical except for a slight ventral sinuosity; surface ornamented by fine concentric striae.

Dimensions.—Holotype, length, 49.8 mm.; height, 12 mm.; convexity (both valves), 5.5 mm.

Type locality.—Seven miles west of Champerico, Guatemala, in 14 fathoms (25 meters), lat. 14° 13′ N., long. 92° 02′ W.

Repository.—California Academy of Sciences Paleontological Type Collection, No. 9155.

Discussion.—As the specimen chosen as holotype was well figured by Hertlein and Strong, no additional figure is given here. The range of the species seems to be from Acapulco, Mexico, to Ecuador. Additional material is in the California Academy of Sciences collection.

The specific name is a Latin adjective meaning "knife-formed," in reference to the bladelike outline of the shell.

Family **SPONDYLIDAE**

Genus **Plicatula** Lamarck, 1801

Système des Anim. s. Vert., p. 132. Type (subsequent selection, Anton, 1839), *Spondylus plicatus* Linné, 1767.

Plicatula anomioides Keen, n. sp. Pl. 31, figs. 4, 7, 8

Description.—Shell nearly circular in outline, white, thin, with faint divaricating radial ribs, especially near the beaks; interior shining white, with, on most specimens, one or more greenish blotches. Lower valve firmly cemented to substrate and, therefore, tending to reproduce the irregularities of its surface. Hinge strong, with two serrate crura in either valve, difficult to disengage without damage to the shell. Coalesced adductor muscle scars large and slightly posterior to a line drawn vertically through the beaks.

Dimensions.—Holotype, major diameter (length), 33 mm.; minor diameter (height), 30 mm.; convexity (both valves), about 6 mm. Largest paratype, diameter, 50 mm.; convexity, 10 mm.

Type locality.—Guaymas, Sonora, Mexico, on breakwater in front of Miramar Hotel.

Repositories.—Holotype, Stanford University Paleontological Type Collection, No. 8500; paratypes, Nos. 8500-a-b (on same piece of rock), 8501. Other paratypes to be deposited in collections of: U. S. National Museum, California Academy of Sciences, British Museum (Natural History), San Diego Society of Natural History, Paleontological Research Institution, No. 25352, Muséum d'Histoire Naturelle de Paris, and Dr. S. S. Berry.

Discussion.—This form is apparently common at the type locality and has been overlooked because of its close resemblance to the abundant Anomias that occupy the same habitat. It is readily distinguished from the other three tropical West American Plicatulas by its pure white exterior, internal patches of greenish-brown color, and nearly obsolete ribbing. *P. penicillata* Carpenter, 1856, is thin and white but has radiating stripes of brown, and the surface is scaly to spinose. *P. spondylopsis* Rochebrune, 1895 (of which *P. ostreivaga* Rochebrune, 1895, is the juvenile form), is pinkish-brown in color, rounded, with numerous well-developed divaricating radial ribs. The type specimen has not been figured, but a photograph recently received from the Muséum d'Histoire Naturelle de Paris shows that it is not the form so identified by authors and figured by Hertlein and Strong (Zoologica, vol. 31, pl. 1, figs. 15-16, 1946). The latter, a coarsely ribbed, triangular to ovate form, brownish outside and streaked around the margin with brown within, may be assimilated to *P. inezana* Durham, 1950 (Geol. Soc. Amer., Mem. 43, p. 68, pl. 13, figs. 1, 3, 6), which was described as a Pleistocene fossil from the Gulf side of Lower California.

The name *anomioides* has been applied in reference to the *Anomia*-like appearance of this shell.

Family **VENERIDAE**

Subfamily **CHIONINAE**

Genus **Chione** Megerle von Mühlfeld, 1811

Mag. Ges. Freunde Berlin, vol. 5, p. 51. Type (subsequent selection, Gray, 1847), "*Venus dysera* Linné" of Gmelin, 1791 (not of Linné, 1758) = *Venus cancellata* Linné, 1767.

Subgenus **Chionista** Keen, n. subg.

Type species, *Chione* (*Chionista*) *fluctifraga* (Sowerby) = *Venus fluctifraga* Sowerby, 1853.

Description.—Lacking the bevelled escutcheon and incised lunule of *Chione* but otherwise similar. Shells rounded to trigonal, medium to large in size, with concentric sculpture predominating, of smooth, rounded ribs; internal margin denticulate through its entire length.

Discussion.—The subgenus includes two Recent species, *C. fluctifraga* and one that has been called by some collectors *Chione gibbosula* (Deshayes). Deshayes' name was applied only in manuscript and was published by Reeve, 1863, over the figure of a shell (from an unknown locality) that seems to be *C. fluctifraga.* Carpenter in 1864 (Suppl. Rept. Brit. Assoc. Adv. Sci. for 1863, p. 570), in a review of Reeve's monograph, commented:

> *Venus gibbosula* Desh., MS in Mus. Cum. Hab.?—[Guaymas: =*V. cortezi* Sloat. This is the more rounded and porcellaneous form of *V. fluctifraga* . . . Interior margin very finely crenated on both sides of hinge.].

Although the name thus introduced—*V. cortezi* Carpenter, *ex* Sloat MS.—comes close to being a *nomen nudum*, I think a case could be made for it within the framework of the International Code, for Opinion 52 rules that although statement of a type locality is insufficient as description of a species, if there is supplementary citation of morphological characters, the locality may then be taken into account in recognition of the form. Carpenter's mention of Guaymas favors the separation of the two species. *C. fluctifraga* occurs there only sparsely, the more porcellaneous *C. cortezi* being the dominant form, which I should describe as trigonal, however, rather than rounded in shape. *C. fluctifraga* ranges from southern California, where it is fairly common, to Guaymas, Sonora, Mexico, where it is rare. *C. cortezi* (Carpenter), distinguished by its larger size, greater solidity, and more ovate outline, has been recorded from near Magdalena Bay, on the outer coast of Lower California, and in the northeastern part of the Gulf of California, from San Felipe to Guaymas.

Parker (Jour. Paleont., vol. 23, p. 593, 1949) considered that *C. fluctifraga* should be classed as a *Protothaca* because it lacks an escutcheon. However, the small pallial sinus and the form of the hinge teeth are those of *Chione.* A relationship to the New Zealand *Austrovenus* Marwick was suggested by Hertlein and Strong (Zoologica, vol. 33, p. 193, 1948), but this group has an incised lunule and the posterior margin of the right valve laps over the left, as in *Chione*, whereas in these two species the valves meet squarely. A new subgeneric name thus seems to be warranted.

Family **TELLINIDAE**

Genus **Macoma** Leach, 1819

In Ross, Voy. Discovery Baffin Bay, App. II, p. lxii. Type species (monotypy), *M. tenera* Leach=*Tellina calcarea* Gmelin, 1791.

Subgenus **Psammacoma** Dall, 1900

Proc. U. S. Nat. Mus., vol. 23, No. 1210, p. 292. Type species (original designation), "*Psammotaea candida* Lamarck of Bertin"=*Psammotaea candida* Lamarck, 1818.

Macoma (Psammacoma) elytrum Keen, n. sp. Pl. 30, fig. 14

Tellina elongata Hanley, 1844. Proc Zool. Soc. London for 1844, p. 144 [not *T. elongata* Dillwyn, 1823, *ex* Solander MS.]. Type locality, Chiriqui, Panama.

Description.—Shell white, under a grayish-green periostracum, elongate-quadrate, with a radial depressed area on the lower middle part of the anterior end; surface nearly smooth, with fine concentric growth lines coarser posteriorly and with slight irregular oblique striations along the posterior umbonal ridge. Hinge with two cardinal teeth in either valve, the right anterior cardinal a little roughened in large specimens, the right posterior and the left anterior slightly bifid. Pallial sinus rounded in front, rising higher behind, projecting to the anterior third of the shell, confluent along the base for about half its length.

Dimensions.—Holotype, length, 47 mm.; height, 25.5 mm.; convexity, (both valves), 13.2 mm. Hypotype (here figured), length, 48.2 mm.; height, 27 mm.; convexity, 13.7 mm.

Type locality.—South-southwest of Maldonado Point, Mexico; locality of hypotype, Monypenny Point, Gulf of Fonseca, Nicaragua, in 4-7 fathoms.

Repository.—Holotype, California Academy of Sciences, Paleontological Type Collection, No. 10503; hypotype, No. 10504.

Discussion.—Several additional lots from other localities are in the California Academy collection. According to Hertlein and Strong (*op. cit.*, vol. 34, p. 90), the range is from Lower California to Panama. The species is an offshore form rarely if ever found on the beach.

A hypotype is figured here, and the holotype will be figured in the forthcoming handbook. This specimen shows patches of the periostracum that is characteristic of this form, which gives the illustration a mottled appearance.

The specific name is from the Greek noun *elutron*, meaning "sheath" or "cover," referring to the outline of the shell, which somewhat resembles the wing-covers of a large beetle.

Family **SEMELIDAE**

Genus **Leptomya** A. Adams, 1864

Ann. Mag. Nat. Hist., ser. 3, vol. 13, p. 208. Species included: *Scrobicularia adunca* Gould, 1861, and *Neaera cochlearis* Hinds, 1844. Type species (selected by Stoliczka, 1871), *N. cochlearis* Hinds.

Shell somewhat triangular in outline, the posterior end pointed. Ligament in two parts, the outer ligament small, the inner ligament in a narrow resilifer that is embedded in the hinge plate and does not project below the hinge margin. Left valve with one, right valve with two small cardinal teeth and no laterals. Pallial sinus large and confluent with the pallial line.

A review of the known species of *Leptomya* has been given by Lamy (Jour. de Conchyl., vol. 61, No. 3, pp. 243-368, 1914) which may be summarized briefly, with subsequent additions, as follows:

adunca (Gould, 1861). Japan. Figured by Habe, 1952, figs. 518-519.
aucklandica Powell, 1955. New Zealand. Subspecies of *L. retiaria.*
bracheon (Sturany, 1901) [*Raeta*]. Red Sea.=*L. cochlearis, fide* Lamy.
cochlearis (Hinds, 1844). Japan, Philippines. Type figured by Hanley, 1882.
cuspidariaeformis Habe, 1952. Gen. Japanese Shells, Pelecypoda, No. 3, p. 209, figs. 505-507. Japan.
gravida Hanley, 1879. Loc. —?
lintea (see *retiaria*)
luzonica Preston, 1906. Philippines.
nitida (Adams and Reeve, 1850) [*Poromya*]. Borneo.
perconfusa (see *retiaria*)
psittacus Hanley, 1882. Queensland.
retiaria (Hutton, 1885) [*Tellina*]=*T. lintea* Hutton, 1873 [not *T. lintea* Conrad, 1837]; needlessly renamed *L. perconfusa* Iredale, 1915.
rostrata (H. Adams, 1868) [*Scrobicularia*]. Seychelle Islands.
spectabilis Hanley, 1882. Japan, Siam. =*L. subrostrata, fide* Lamy.
subrostrata (Issel, 1869) [*Syndosmya*]. Red Sea. A variety of *L. rostrata, fide* Lamy.
trigonalis (Adams and Reeve, 1850) [*Thracia*]. Sulu Seas.

It is interesting to notice that eight different generic names were invoked by authors for the 15 species listed above. The distribution of these species, where known, was in the southern and western Pacific and westward to the Red Sea. No Atlantic or eastern Pacific forms are recorded. The specimens here to be described were collected by a Stanford graduate, Robert van Vleck Anderson, in Panama in 1913. These two valves had been set aside as an unidentified *Macoma*, and not until a few months ago, when I took a second look at the hinge, did I realize the true relationships. A second set of specimens—also labelled *Macoma* sp.—has since come to light at the California Academy of Sciences.

Leptomya americana Keen, n. sp. Pl. 30, figs. 9-10; Pl. 31, figs. 3, 5, 6

Description.—Shell thin, yellowish white, inequilateral, somewhat inflated anteriorly, rounded trigonal to oblique, the anterior margin smoothly rounded, the posterior ventral margin somewhat angulate but not so pointed as in most other species of the genus, with a low ridge along the posterior dorsal margin; surface smooth except for incremental lines. Hinge with the nymph for the exterior ligament weak and the resilium more deeply embedded in the right than in the left valve, the hinge plate relatively narrow.

Dimensions.—Holotype, a left valve, length, 33 mm.; height, 22.7 mm.; convexity, 6.5 mm.; paratype, a right valve, length, 26 mm. [incomplete], height, 19 mm.; convexity, 6 mm. Hypotypes: six unmatched valves, with the following dimensions (length, height, and convexity being given in order): a) 27/19.5/5.7 mm.; b) 24.5/16.5/5 mm.; c) 23/16.3/5 mm.; d) 22/16/4.6 mm.; e) 19.2/13.2/4 mm.; f) 16/12.2/3.5 mm.

Type locality.—East side of Punta Alegre, San Miguel Bay, Panama. Collector, Robert van Vleck Anderson, 1913. Hypotypes from a muddy area near the mouth of Rio Esmeraldas, Ecuador, collected by R. Hoffstetter, about 1950.

Reposities.—Holotype, Stanford University Paleontological Type collection, No. 8504; paratype, No. 8504a; hypotypes, California Academy of Sciences, Nos. 10505, 10505 a-e.

Discussion.—The hypotypes form a growth series, none being as large as the holotype and paratype; some of them are more pointed than others but all are more ovate than the western Pacific Leptomyas. As compared with the type species of the genus, a specimen of which is in the Stanford collection, *L. americana* is a thinner and more fragile shell, less pointed posteriorly. Specimens of *L. retiaria*, also available for comparison, are smaller, with relatively longer hinge teeth. Study of figures of the other named species reveals none that are identical in form with this, although *L. rostrata* and *L. gravida* somewhat approach it, both being, however, relatively longer posteriorly. Although the genus has not been reported hitherto in the eastern Pacific, it is possible that specimens have been taken by collectors and have been misidentified as either *Macoma* or *Apolymetis*, for the exterior resemblance to these is close.

Class GASTROPODA

Family **CALYPTRAEIDAE**

Genus **Crucibulum** Schumacher, 1817

Ess. Nouv. Syst. ver. Test., p. 182. Species included: *C. rugoso-costatum* and *C. planum.*

Type species (here selected), *C. planum* Schumacher=*Patella auricula* Gmelin, 1791. West Indies.

Previous selections of the type species, so far as I can discover, have been of species not mentioned in the original list; for example, Hermannsen, March, 1847—*P. chinensis*; and Gray, Nov. 1847—*P. auriculata.* Other authors, such as Wenz, 1940, have cited *P. scutellata* Gray, a West American species not then described and, therefore, unknown to Schumacher.

Crucibulum personatum Keen, n. sp. Pl. 30, figs. 6-8

Calyptraea radiata Broderip, 1834, Proc. Zool. Soc. London for 1834, p. 36 [not *C. radiata* Deshayes, 1830]. Type locality, "Bay of Caraccas."

Description.—Shell conical, white or with faint brownish radial markings, finely sculptured with radiating threads of two sizes. Apex subcentral, brownish, not recurved. Interior white mottled with brown, the cup flattened, partially attached to the outer wall, and well removed from the margin.

Dimensions.—Holotype, length, 17 mm.; width, 14 mm.; height, 10 mm.

Type locality.—Panama. Collector, James Zetek.

Repositories.—Holotype, Stanford University Paleontological Type Collection, No. 8498; paratype, No. 8499. Additional paratypes to be deposited in collections of U. S. National Museum, California Academy of Sciences, Paleontological Research Institution, No. 25351, San Diego Society of Natural History, Muséum d' Histoire Naturelle de Paris, Dr. S. S. Berry.

Discussion.—This has been confused with *C. spinosum* by some workers, but the two are separable on several counts: the radiating ribs are never spinose and have none of the oblique secondary patterning so characteristic of *C. spinosum*; the apical whorls are bluntly tapering, not recurved, and are nearly central; and the internal cup is partially appressed to the wall of the shell, not free-standing. The range seems to be from Acapulco, Mexico, to Panama.

The specific name, *personatum*, is a Latin adjective meaning "masked" or "counterfeit," chosen in reference to the confusion of this shell by some collectors with the much more common *C. spinosum*.

Family **MURICIDAE**

Genus **Aspella** Mörch, 1877

Malak. Blätter, Bd. 24, p. 24. Type species (monotypy), *Ranella anceps* Lamarck, 1822.

Shell with two or more varices, the surface of the whorls cancellately ribbed, with fine overlying spiral striae that give a worn look to the fresh shell.

Subgenus **Dermomurex** Monterosato, 1890

Poweria Monterosato, 1884, Nomencl. Conch. Medit., p. 113 [not Bonaparte, 1840].

Dermomurex Monterosato, 1890. Natural. Sicil., vol. 9, p. 181. Type species (original designation), *Murex scalarina* Bivona, 1832 = *M. scalarioides* Blainville, 1829. Mediterranean.

Varices more than two per whorl, normally three.

Aspella (Dermomurex) perplexa Keen, n. sp. Pl. 30, figs. 11-13

Description.—Shell white, biconic, with varices that run diagonally up the spire, seven on the body whorl, the four alternate varices larger; nuclear whorls two, smooth, post-nuclear whorls six; sculpture somewhat nodose rather than cancellate, the surface finely spirally striate; aperture ovate, the outer lip smooth within, the canal open.

Dimensions.—Holotype, length, 30.5 mm., diameter, 15 mm.; length of aperture, 14 mm.; hypotypes, height 19.8 and 15 mm., diameter 12 and 8 mm., respectively.

Type locality.—Perlas Islands, Panama. Holotype collected by Walter D. Clark, 1943. Hypotypes, Zihuatanejo, Guerrero, Mexico, collected by Jeanne Frisbey, 1956.

Repositories.—Holotype, Stanford University Paleontological Type Collection, No. 8496; hypotype, No. 8497; a second hypotype in the collection of Mrs. W. C. Frisbey, Port Isabel, Texas.

Discussion.—From *Aspella erosa* (Broderip) this is separated by the number of varices and the biconic outline. It is closer to the *A. alveata* (Kiener, 1843) of authors, supposedly a Caribbean form, but is larger, with sculpture not markedly clathrate. Until more material comes to light one cannot be sure whether a single species, two subspecies, or two separate species are represented by the material here illustrated; hence, the conservative view is taken that the two hypotypes, which are badly worn, comprise a stubby variant. These two specimens are not cited as paratypes, not being from the type locality. Rather, they probably indicate the northern terminus of range of the species—Zihuatanejo, Mexico. If these two specimens are conspecific with the Panama holotype, they show also that under the uniform grayish-white surface layer there are several brown color bands (five to six in the larger hypotype).[1]

Family **CANCELLARIIDAE**

Genus **Cancellaria** Lamarck, 1799

Mem. Soc. Hist. Nat. Paris, vol. 1, p. 71. Type species (monotypy), *Voluta reticulata* Linné, 1758.

Subgenus **Narona** H. and A. Adams, 1854

Genera Rec. Moll., vol. 1, p. 277. Type species (selected by Cossmann, 1899), *Cancellaria clavatula* Sowerby, 1832.

Differing from *Cancellaria, s. s.,* in having a tapering spire and narrower aperture. First spire whorl bicarinate, adult sculpture with swollen axial ribs.

Cancellaria (Narona) jayana Keen, n. sp. Pl. 30, fig. 5

Description.—Shell nearly biconic, spire slender, aperture pear-shaped, widest above center; color pinkish-buff; sculpture of strong axial ribs (11 on body whorl of the holotype), crossed by several spiral cords (4 on spire whorls, 10 on body whorl) that form low nodes at the intersections, the second cord below the suture larger, standing out as a slight shoulder. Whorls about seven in number. Columella with three folds, the upper most more that twice as wide as the next.

Dimensions.—Holotype, height, 24.3 mm.; diameter, 12.5 mm.

Type locality.—Panama Bay, about 1 mile off entrance to Panama Canal, depth about 10 fathoms. Collector, Walter D. Clark, 1944.

Repositories.—Holotype, Stanford University Paleontological Type Collection, No. 8502; paratype, No. 8503. Other paratypes to be deposited in collections of California Academy of Sciences, U. S. National Museum, and Paleontological Research Institution, No. 25353.

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[1] Additional specimens from Mexico, seen while this paper was in press, indicate that the Mexican variant is consistently shorter, with color banding in the adult, and that it ranges north at least as far as Mazatlan. Only beachworn specimens have been available for study, however, not of a quality to warrant bestowal of a new name at this time.

Discussion.—*C. jayana* differs from the other Panamic Naronas in the strongly latticed sculpture; it is larger than *C.* (*N.*) *elata* Hinds, smaller than *C. clavatula* Hinds and *C. exopleura* Dall. It is perhaps nearest to the Ecuadorean Pliocene form *C.* (*N.*) *pajana* Pilsbry and Olsson, 1941 (Acad. Nat. Sci. Philadelphia, Proc., vol. 93, p. 25, pl. 3, fig. 6) but is larger, has a more definite shoulder to the whorls, and has fewer axial ribs. The six specimens of the type lot form part of a collection of uncommon material salvaged during World War II by Mr. Clark from dredgings in Panama Bay when the entrance to the Canal was deepened. Two previous reports on the material from this unusual station are by Li (Bull. Geol. Soc. China, vol. 9, pp. 249-296, pls. 1-8, 1930)—who thought that the specimens were well-preserved Miocene (Gatun) fossils—and by Pilsbry (Acad. Nat. Sci. Philadelphia, Proc., vol. 83, pp. 427-440, pl. 41, 1931), who recognized their true affinities. All of the specimens seem to be dead shells, although some of them are only recently so. Other species collected by Mr. Clark at this locality are: *Cancellaria balboae* Pilsbry, *Clathrodrillia inaequistriata* (Li), *Cosmioconcha modesta* (Powys), *Metula amosi* Vanatta, *Phos crassus* Hinds, *Terebra cracilenta* Li, and *T. melia* Pilsbry.

The species is dedicated to Dr. Jay Glenn Marks, who first recognized it as new and whose report on the family Cancellariidae (Jour. Paleont., vol. 23, No. 5, pp. 453-464, 1949) greatly facilitated the writing of this description.

Family **TURRIDAE**

Genus **Gemmula** Weinkauff, 1875

Jahrb. deutsch. malak. Ges., vol. 2, p. 285. Type species (selected by Cossmann, 1896): "*Pleurotoma gemmata* Reeve, 1843."

Posterior apertural notch forming a beaded slit-band that stands out as a slight carina.

Gemmula sp. Pl. 30, figs. 1-4

Pleurotoma gemmata Reeve, Apr., 1843, *ex* Hinds MS., Conch. Icon., vol. 1, *Pleurotoma*, pl. 10, fig. 83 [not *P. gemmata* Conrad, 1835]. Magdalena Bay, Lower California, in 7 fathoms. Also described by Hinds, Proc. Zool. Soc. London for 1843, p. 37 (Oct., 1843) and figured in Zool., Voyage of the Sulphur, 1844, p. 15, pl. 5, fig. 4.

Discussion.—It is unfortunate that the name of the type species of *Gemmula* must be abandoned, but since it is a primary homonym, no other course is open. As Dr. S. S. Berry has a replacement name in manuscript[2], I include here only a mention of the homonym and some notes upon and figures of two specimens collected by the Orca Expedition in 1950 that are in the collection of the San Diego Society of Natural History. The smaller of the two specimens is the closer to the original figure and has the nuclear whorls complete. The larger shell has one more whorl and its greater relative diameter suggests that some variation in proportions within this rare species may be expected. Mr. I. C. J. Galbraith (letter dated November 12, 1957) reports that Hinds' specimen is in the British Museum (Natural History), under the register No. 1897 2.26.34 and that it is slightly smaller than the figures given by Reeve and by Hinds. It must therefore be not far from the size of the specimens figured here. Mr. E. P. Chace (*in litt.*) states that the locality label of the dredge lot from which this material came was badly scuffed and only partially legible but that the station was probably off Angel de Guarda Island, Gulf of California. In any case, they prove incontestibly that the species occurs in moderately shallow water along some part of the Lower California coast, a locality that was questioned by Tryon. Dall described several other species from deep water (more than 100 fathoms) off the Central American coast, but in the main the genus is western Pacific in distribution.

ACKNOWLEDGMENTS

I wish to express my thanks to the California Academy of Sciences for supplying the photograph of *Macoma* and for access to their collections; to Dr. S. Stillman Berry, Mr. Emery P. Chace, and the San Diego Society of Natural History for the loan of specimens; and to Mr. Robert Robertson for reference work at Harvard University library. My greatest debt, of course, is to the collectors, Mrs. W. C. Frisbey, Robert van Vleck Anderson (deceased), Walter D. Clark, and John P. Strohbeen,—whose donation of material to Stanford University gave me the privilege of publishing these new records.

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[2] Published while this paper was in press as *Gemmula hindsiana* Berry, Leaflets in Malac., vol. 1, No. 15, p. 86 (March 28, 1958).

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PLATES

EXPLANATION OF PLATE 30

Figures Page

1-4. **Gemmula** sp. 250

1. Hypotype, San Diego Soc. Nat. Hist., No. 12987; x 2. 2. Hypotype, SDSNH, No. 12986; x 2. Off Angel de la Guarda Island, Gulf of California. 3. Apical whorls of hypotype, No. 12986 x 9. 4. Labial profile of same specimen, broken margin restored by dotted lines; x 6.

5. **Cancellaria (Narona) jayana** Keen, n. sp. 249

Holotype, Stanford Univ. Paleo. Type Coll., No. 8502; x 1.5. Panama Bay, in about 10 fathoms.

6-8. **Crucibulum personatum** Keen, n. sp. 247

6. Holotype, viewed from above. Stanford Univ. Paleo. Type Coll., No. 8498, x 2. 7. Detail of sculpture; x 10. 8. Paratype, interior view. SU, No. 8499; x 2. Panama.

9, 10. **Leptomya americana** Keen, n. sp. 246

9. Paratype, right valve, Stanford Univ., No. 8504a, x 1.5. 10. Holotype, left valve, SU, No. 8504; x 1.5. Punta Alegre, San Miguel Bay, Panama.

11-13. **Aspella (Dermomurex perplexa** Keen, n. sp. 248

11. Holotype, Stanford Univ., No. 8496; x 1.5. Perlas Islands, Panama. 12. Hypotype, SU, No. 8497. 13. Hypotype, collection of Mrs. W. C. Frisbey; x 1.5. Both from Zihuatanejo, Mexico.

14. **Macoma (Psammacoma) elytrum** Keen, n. sp. 244

Hypotype, Calif. Acad. Sci., No. 10504; x 1.1. Monypenny Point, Gulf of Fonseca, Nicaragua.

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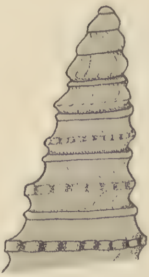
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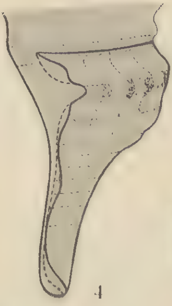
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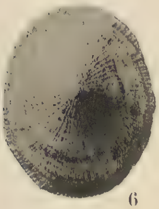
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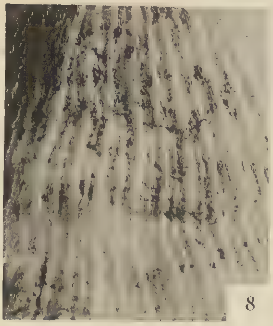
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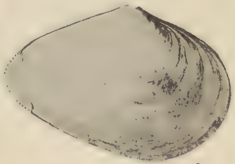
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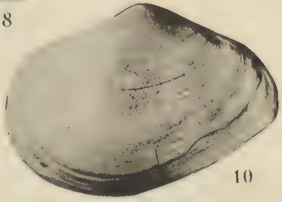
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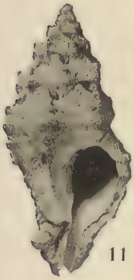
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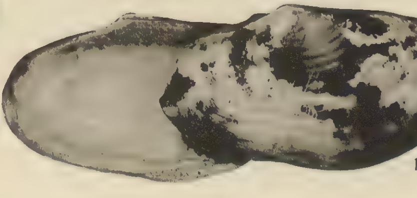
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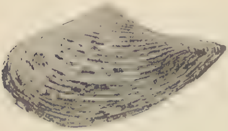
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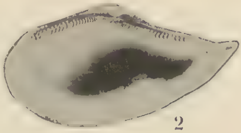
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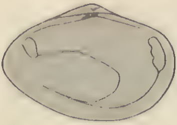
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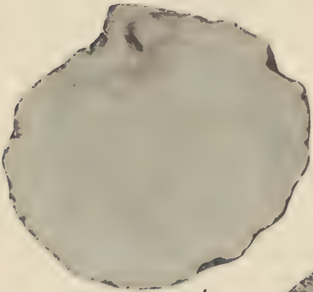
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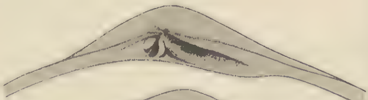
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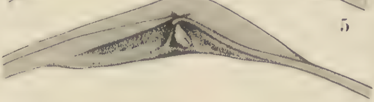
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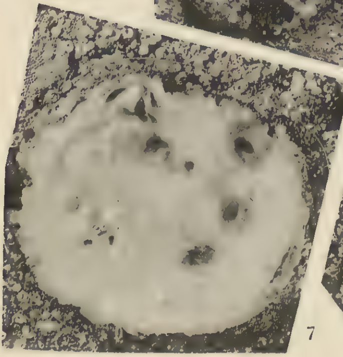
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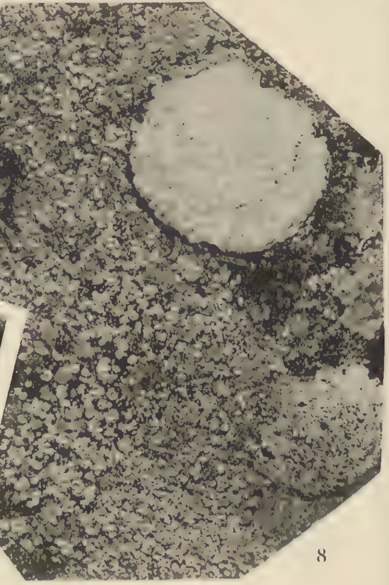
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EXPLANATION OF PLATE 31

Figures Page

1, 2. **Nuculana (Saccella) fastigata** Keen, n. sp. 240

Holotype, Calif. Acad. Sci. Paleo. Type Coll., No. 9149. 7. Exterior of left valve; 2. Interior of right valve; x 1.1. Off Ballenas Bay, Gulf of Nicoya, Costa Rica.

3, 5, 6. **Leptomya americana** Keen, n. sp. 246

3. Interior of holotype, x 0.9; 5. Hinge of right valve, x 4; 6. Hinge of left valve, holotype; x 4. Panama.

4, 7, 8. **Plicatula anomioides** Keen, n. sp. 241

4. Holotype, interior of left valve, Stanford Univ. Paleo. Type Coll., No. 8500, x 1.5. 7. Interior of right (attached) valve; x 1.5. 8. Holotype and two paratypes (Nos. 8500 a-b) in place, holotype cleaned of encrusting algae, Bryozoa, and annelid worm tubes [*Spirorbis* sp.]; paratypes (at left and lower right) in natural state; x 1. Guaymas, Sonora, Mexico.

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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA, PARTICULARLY THE CAMERINIDS — No. 2

By

W. Storrs Cole
Cornell University, Ithaca, New York

May 29, 1958

Paleontological Research Institution
Ithaca, New York, U. S. A.

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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA, PARTICULARLY THE CAMERINIDS—NO. 2†

W. Storrs Cole
Cornell University, Ithaca, New York

ABSTRACT

Most of the American Paleocene to Miocene species of camerinids are reviewed and a key for the identification of species of *Operculinoides* is given. The following genera are represented by only one species each: *Operculina, Paraspiroclypeus,* and *Spiroclypeus.* There are two species of *Camerina,* four species of *Heterostegina,* and eight species of *Operculinoides.* A new generic name, *Planocamerinoides*, is proposed for specimens generally referred by authors to *Assilina* d'Orbigny, 1839, as *Assilina* is a synonym of *Operculina* d'Orbigny, 1826. *Planocamerinoides* is not known to occur in the American Eocene. *Asterocyclina georgiana* (Cushman) is a synonym of *A. asterisca.*

INTRODUCTION

Although American larger Foraminifera have been studied intensively over the past 30 or so years, there are many points which still need clarification. During that time many specific names were erected which upon detailed study prove to be synonyms. Such a pattern is to be expected as many of the species were described either from inadequate material or from few thin sections. Moreover, most authors believed that species of larger Foraminifera had limited stratigraphic range. Slight differences in individuals caused by environmental factors, such as thickness of walls, were magnified to a degree that these were interpreted as genetically produced characters which could be used to define a species.

For many years *Asterocyclina georgiana* (Cushman, 1917) and *Asterocyclina asterisca* (Guppy, 1866) have been recognized as distinct species. Although these species are similar and occur at the same stratigraphic horizon, no one has to date questioned their separate identities. However, it is obvious that only one species should be recognized. If the vertical section (Pl. 33, fig. 13) of a specimen from Trinidad identified as *A. asterisca* by Vaughan and Cole, (1941, p. 60) is compared with a vertical section identified by Cole (1949, pl. 55, fig. 4) as *A. georgiana*, it will be observed that the internal structure is identical. Thus, *A. georgiana* is a synonym of *A. asterisca.*

During the past few years the writer has been studying American species of camerinids. This article is a continuation of those studies in which an attempt is made to summarize certain conclusions formulated to this time. Material already reviewed (Cole, 1953; 1956*b*; 1958*a*; 1958*b*, Sachs, 1957) will not be repeated.

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†The cost of the printed plates was supplied by the William F. E. Gurley Foundation for paleontology of Cornell University.

Four basic facts have evolved from these studies: 1) there are few American species of camerinids; 2) certain species have much longer stratigraphic ranges than were assigned to them previously; 3) individuals within a species show decided minor structural differences which are apparently caused by environmental factors; and 4) most of the species have a wide geographic distribution around the Caribbean area.

A key to the genera of American Paleocene to Miocene camerinids follows:

KEY TO GENERA

A. Median chambers without chamberlets
  1. Evolute, normally compressed
    a. Chambers of the median section always showing a marked increase in height .... *Operculina*

    b. Chambers of the median section increasing gradually in height .... *Planocamerinoides**

  2. Involute, compressed or inflated

    a. Without vacuoles in the spiral sheet (revolving wall)
      1′. Chambers of the median section always showing a marked increase in height .... *Operculinoides*
      2′. Chambers of the median section increasing gradually in height, never with a marked increase in height........ *Camerina*

    b. With vacuoles in the spiral sheet .... *Paraspiroclypeus*

B. Median chambers with chamberlets
  1. Without lateral chambers .... *Heterostegina*
  2. With well-developed lateral chambers .... *Spiroclypeus*

All the genera, with the exception of *Planocamerinoides*, are found in parts of the Tertiary of America. This genus, however, is known to-date only from Europe, Africa, and Asia.

**Planocamerinoides*, new generic name, the type of which is here designated as *Nummulites exponens* Sowerby, 1840, is given to those evolute, compressed camerinids which have been referred generally by authors to *Assilina* d'Orbigny, 1839. Cushman (1927, p. 189) designated *Nummulina discoidalis* d'Orbigny as the type of *Assilina*. However, it is well established that *N. discoidalis* is a Recent *Operculina* (see: Chapman and Parr, 1937, p. 290). Therefore, *Assilina* becomes a synonym of *Operculina* d'Orbigny, 1826.

A key to the species of Paleocene to Miocene *Operculinoides* follows:

KEY TO AMERICAN SPECIES OF OPERCULINOIDES

A. Marginal cord, prominent, coarse .... *O catenula*
(see: Cole, 1953, pl. 2, fig. 4; pl. 3, fig. 11)

B. Marginal cord, moderate to fine . . . . . . Pl. 33, figs. 6-8

- 1. Chambers of final volution typically high, narrow, forming a distinct wide rim .... (see: Cole, 1958*a*, pl. 19, figs. 10, 14)
  - a. Test small, up to 1.75 mm., with $1\frac{3}{4}$ to $2\frac{1}{8}$ volutions
    O. gravelli (see: Cole, 1944, pl. 7, figs. 1, 12)
  - b. Test large, 2 to 16 mm., with $2\frac{1}{4}$ to $3\frac{1}{2}$ volutions
    O. floridensis (see: Cole, 1958*a*, pl. 19, figs. 1, 10)
- 2. Chambers in final volution increasing in height, but not typically high, narrow, either without a rim or with a small rim ....
  Pl. 33, figs. 9-12
  - a. Typically without a rim
    - 1′. Chamber walls in median section without a marked, sharp distal recurvature .... Pl. 33, fig. 9
      - a′. Test small, up to 2.5 mm. in diameter
        - 1″. Marginal cord broadly rounded ....
          O panamensis (see: Cole, 1958*a*, pl. 25, fig. 15)
        - 2″. Marginal cord bluntly angulated ....
          O. trinitatensis (see: Vaughan and Cole, 1941, pl. 13, figs. 1-5)
      - b′. Test typically more than 2.5 mm. in diameter
        . . . . *O. willcoxi* (see. Pl. 33, figs. 1, 3-12)
    - 2′. Chamber walls in median section with a marked, sharp distal recurvature .... *O. dia* (see: Vaughan and Cole, 1936, pl. 37, figs. 2, 7)
  - b. Typically with a rim .... *O. cojimarensis* (Pl. 34, fig. 7)

This key to the species was formulated in an attempt to understand the internal features of average adult specimens. Reference has been made in each case to an illustration which shows a typical individual. As specimens within a given species vary widely in size and detail, and as the internal structures of all the species are similar, a number of specimens must be analyzed to satisfactorily identify a given species by use of the key.

The known stratigraphic range of the American camerinids to-date is:

PALEOCENE AND LOWER EOCENE

Operculinoides catenula (Cushman and Jarvis)

MIDDLE EOCENE

Camerina macgillavryi M. G. Rutten
Operculinoides gravelli Cole

UPPER MIDDLE EOCENE TO UPPER EOCENE

Camerina striatoreticulata (L. Rutten)
Operculinoides floridensis (Heilprin)
willcoxi (Heilprin)

UPPER EOCENE

Heterostegina ocalana Cushman
Operculina mariannensis Vaughan
Operculinoides trinitatensis (Nuttall)

OLIGOCENE

Heterostegina antillea Cushman
israelskyi Gravell and Hanna
panamensis Gravell
Operculinoides dia (Cole and Ponton)
panamensis (Cushman)
Spiroclypeus bullbrooki Vaughan and Cole

MIOCENE

Operculinoides cojimarensis (D. K. Palmer)
Paraspiroclypeus chawneri (D. K. Palmer)

Although this study is directed mainly to the names of and variation in Tertiary species of camerinids, attention should be called at this time to the large number of specific names which have been given to specimens of the Cretaceous genus *Sulcoperculina.* Cole (1947) has discussed variation in this genus. If the various illustrations which have been given of the species which have been proposed in this genus are arranged in sequence, it is doubtful if more than one or two species could be selected from the series. Yet, more specific names are constantly being given.

REVIEW OF SPECIES

Genus **Camerina** Bruguière, 1792

Camerina macgillavryi M. G. Rutten

1935. *Camerina macgillavryi* M. G. Rutten, p. 530 (Cuba).

Remarks.—This species has a megalospheric generation with exceptional large embryonic chambers. The microspheric specimens are large and compressed.

The species was described from Cuba. Recently, the writer has seen specimens from Costa Rica through the courtesy of Richard Weyl and from Haiti through the kindness of J. Butterlin.

Camerina striatoreticulata (L. Rutten) Pl. 32, figs. 1-16

1928*a*. *Nummulites striatoreticulatus* L. Rutten, p. 1068 (Curaçao).
1932. *Nummulites vanderstoki* M. G. Rutten and Vermunt, p. 240 (Curaçao).
1935. *Camerina petri* M. G. Rutten, p. 530 (Cuba).
1935. *Camerina malbertii* M. G. Rutten, p. 531 (Cuba), microspheric specimens.
1938. *Camerina striatoreticulata* (L. Rutten), Barker, p. 49 (Cuba).
1939. *Camerina guayabalensis* Barker, p. 325 (Mexico).
1939. *Camerina vanderstoki* (M. G. Rutten and Vermunt), Barker, p. 322 (Mexico).
1940. *Camerina barkeri* Gravell and Hanna, p. 412 (Mississippi).
1940. *Camerina mississippiensis* Gravel and Hanna, p. 413 (Mississippi).
1941. *Camerina vanderstoki* (M. G. Rutten and Vermunt), Cole, p. 28 (Florida).
1941. *Camerina striatoreticulata* (L. Rutten), Vaughan and Cole, p. 31 (Trinidad).
1942. *Camerina vanderstoki* (M. G. Rutten and Vermunt), Cole, p. 27 (Florida).
1944. *Camerina guayabalensis* Barker, Cole, p. 39 (Florida), pl. 17, fig. 4; not pl. 1, fig. 4; pl. 5, fig. 17; pl. 7, figs. 2, 9, 11, 21; pl. 17, fig. 5, which are *O. floridensis* (Cushman).
1945. *Camerina vanderstoki* (M. G. Rutten and Vermunt), Cole, p. 103 (Florida).
1947. *Nummulites* (*Nummulites*) *dorotheae* Cizancourt, p. 513 (Cuba), microspheric specimens.
1947. *Nummulites* (*Nummulites*) *rutteni* Cizancourt, p. 515 (Cuba).
1949. *Camerina striatoreticulata* (L. Rutten), Cole, p. 269 (Panama Canal Zone).
1952. *Camerina striatoreticulata* (L. Rutten), Cole, p. 8 (Panama Canal Zone).
1953. *Camerina striatoreticulata* (L. Rutten), Cole, p. 31 (general).
1956. *Camerina striatoreticulata* (L. Rutten), Cole, p. 207 (Jamaica).
1958*a*. *Camerina guayabalensis* Barker, Cole, p. 190 (St. Bartholomew).

In 1928 L. Rutten described *Camerina striatoreticulata* from the Seroe di Cueba limestone (upper Eocene) of Curaçao, Dutch West Indies. This species was characterized by the possession of Y-shaped processes on the proximal ends of the chamber walls which are observed in median thin sections parallel to but not centered in the median plane. Later, M G. Rutten and Vermunt (1932, p. 240) described from this same upper Eocene limestone *Camerina vanderstoki.* They stated "Apart from the fact that the anteriorly directed processes at the septa are entirely wanting the diameter of 5 whorls of *N. striatoreticulatus* exceeds the diameter of *N. vanderstoki.*"

In 1935 M. G. Rutten described from the upper Eocene of Cuba *Camerina petri* and *Camerina malbertii.* Rutten (1935, p. 532) stated concerning *C. malbertii* "This form is closely related to the much commoner *C. petri,* but is flatter, larger and has higher chambers." His illustrations show that *C. petri* is based on megalospheric specimens, and that *C. malbertii* represents microspheric specimens. Therefore, it is obvious these two species should be combined.

Barker (1938) restudied topotypes of *C. petri* from Cuba and concluded that *C. petri* was a synonym of *C. striatoreticulata.* He stated "The figures of M. G. Rutten are taken from sections cut in the median plane, and the writer's experience, as also Professor L. Rutten's, show that in such sections the 'anteriorly directed processes' considered characteristic of the species are not visible."

In 1939 Barker (p. 322) referred specimens from the Guayabal formation (upper middle Eocene) of Mexico to *C. vanderstoki* stating ". . . . although it occurs at a lower horizon in Mexico (Claiborne) than in Curaçao (Jackson) it is considered to be at most only a minor variant of Rutten and Vermunt's species."

Cole (1941, p. 28; 1942, p. 27; 1945, p. 103) assigned specimens from the Ocala limestone of Florida to *C. vanderstoki.* Mrs. Cizancourt (1947) described from the upper Eocene of Cuba megalospheric specimens which she named *Nummulites* (*Nummulites*) *rutteni* and microspheric specimens from the same locality which she called *N.* (*N.*) *dorotheae.*

As Cole (1953, p. 31) has stated *C. rutteni* (Cizancourt)=*C. petri* M. G. Rutten=*C. striatoreticulata* (L. Rutten) and *C. dorotheae* (Cizancourt)=*C. malbertii* M. G. Rutten. As *C. malbertii* is here considered to be the microspheric form of *C. striatoreticulata*, there remains only the problem of the relationship of *C. vanderstoki* to *C. striatoreticulata.*

A thin section (Pl. 32, figs. 10, 14) of a specimen similar to those previously assigned to *C. vanderstoki* shows certain chamber walls with

Y-shaped processes on the proximal ends of the chamber walls. As these specimens are similar in all other features to the types of *C. vanderstoki*, it is concluded that all the American upper Eocene species referred to *C. vanderstoki* are *C. striatoreticulata.*

However, certain species of *Camerina* from the upper middle Eocene resemble *C. striatoreticulata.* They are *C. guayabalensis* Barker (1939, p. 325) from the Guayabal formation of Mexico, and *C. barkeri* and *C. mississippiensis*, described by Gravell and Hanna (1940) from the upper middle Eocene of Mississippi.

C. barkeri and *C. mississippiensis* are obviously the same species as they are separated largely on the presence or absence of beads or nodes which is an individual rather than a specific character. Moreover, these specimens from Mississippi are the same as specimens from Mexico which were named *C. guayabalensis.*

Thus, in the upper middle Eocene there would appear to be two species: *C. guayabalensis* and the other Mexican specimens which Barker assigned to the upper Eocene *C. vanderstoki.* In his description of *C. guayabalensis* Barker (1939, p. 325) stated "This species is in many respects similar to *C. vanderstoki* (Rutten and Vermunt), both in exterior and in section, but the latter is generally larger and thicker, does not show such a heavily developed keel (with truncation of the periphery), and in section shows more chambers in the final whorl . . . ."

Specimens from St. Bartholomew and Jamaica at first identified as *C. guayabalensis* are illustrated on Plate 32, figures 1-9. As these specimens were studied and compared with specimens previously called *C. barkeri, C. mississippiensis, C. guayabalensis* and *C. vanderstoki*, it was discovered that an integrated series was formed, representing only one species, which in turn merged with the series which results from a comparison of the various illustrations which have been given of *C. striatoreticulata.*

Measurements of the specimens illustrated follow:

MEASUREMENTS OF CAMERINA STRIATORETICULATA (L. RUTTEN)

Median sections*

Locality	W-448, Fla.		Near Mayo, Fla.	V-109, Jamaica		17*a*, St. Bartholomew
Specimen	Pl. 32, fig. 10	Pl. 32, fig. 15	Pl. 32, fig. 16	Pl. 32, fig. 6	Pl. 32, fig. 7	Pl. 32, fig. 5
Height . mm.	3.2	3.05	2.55	2.35	2.53	1.8
Width .... mm.	3.1	3.05	2.55	2.4	2.45	1.45
Embryonic chambers:						
Diameters of initial chamber .. . . μ	100x120	120x135	110x120	60x70	60x70	90x80
Diameters of second chamber .... μ	90x150	95x150	80x130	50x90	45x90	60x80
Distance across both chambers .... μ	220	230	200	130	110	170
Whorls	5	5	4½	5⅛	4¾	4
Chambers in first volution	8	8	8	8	8	8
Chambers in final volution	26	23	27	22	19	17
Total number of chambers	90	80	78	73	66	45+

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*For locality description see explanation of plates.

MEASUREMENTS OF CAMERINA STRIATORETICULATA (L. RUTTEN)

Transverse sections*

Locality	W-448, Fla.		Near Mayo, Fla.	V-109, Jamaica		St. Bartholomew		
						17*b*	17*a*	
Specimen	Pl. 32, fig. 12	Pl. 32, fig. 13	Pl. 32, fig. 11	Pl. 32, fig. 9	Pl. 32, fig. 8	Pl. 32, fig. 4	Pl. 32, fig. 2	Pl. 32, fig. 3
Height mm.	1.88	3.1	2.6	2.75	2.05	2.65	2.2	2.38
Thickness at center mm.	1.05	1.6	1.2	1.15	1.0	1.15	0.9	0.96
Surface diameter of umbonal plugs μ	400	1000	600	700	380	550	350	500

*For locality description see explanation of plates.

Genus **Operculinoides** Hanzawa, 1935

Operculinoides catenula (Cushman and Jarvis)

1932. *Operculina catenula* Cushman and Jarvis, p. 42 (Trinidad).
1957. *Operculinoides bermudezi* (D. K. Palmer), Sachs, p. 107 (references).

Remarks.—Although Cole (1953, p. 37) hesitated previously to place *O. bermudezi* in the synonymy of *O. catenula*, these studies demonstrate that it is logical to do this now. Although *O. catenula* is known only from its external appearance, it so resembles typical specimens of *O. bermudezi* that these species cannot be separated.

Operculinoides cojimarensis (D. K. Palmer) Pl. 34, fig. 7

1934. *Operculinella cojimarensis* D. K. Palmer, p. 259 (Cuba).
1935. *Operculina tuxpanensis* Thalmann, p. 603 (Mexico).
1936. *Operculinoides tuxpanicus* Vaughan and Cole, p. 494 (Mexico).
1938. *Operculinoides tuxpanensis* (Thalmann), Cole, p. 38 (Florida).
1939. *Operculinoides tuxpanensis* (Thalmann), Barker, p. 311 (Mexico).
1941. *Operculinoides tamanensis* Vaughan and Cole, p. 43 (Trinidad).
1941. *Operculinoides tuxpanensis* (Thalmann), Vaughan and Cole, p. 45 (Trinidad).
1958*b*. *Operculinoides cojimarensis* (D. K. Palmer), Cole, p. 224 (Carriaçou).

Remarks.—The transverse section of a topotype which was described previously (Cole, 1958*b*, p. 224) is illustrated.

Operculinoides dia (Cole and Ponton) Pl. 34, figs. 2-4, 6, 9

1930. *Operculinella dia* Cole and Ponton, p. 37 (Florida).
1936. *Operculinoides vicksburgensis* Vaughan and Cole, p. 490 (Mississippi).
1936. *Operculinoides semmesi* Vaughan and Cole, p. 491 (Mexico).
1936. *Operculinoides antiguensis* Vaughan and Cole, p. 492 (Antigua).
1936. *Operculinoides forresti* Vaughan and Cole, p. 493 (Antigua).
1937. *Operculinoides ellisorae* Gravell and Hanna, p. 522 (Texas).
1937. *Operculinoides howei* Gravell and Hanna, p. 523 (Texas).
1938. *Operculinoides forresti* Vaughan and Cole, Cole, p. 37 (Florida).
1939. *Operculinoides muiri* Barker, p. 312 (Mexico).
1939. *Operculinoides antiguensis* Vaughan and Cole, Barker, p. 313 (Mexico).
1939. *Operculinoides semmesi* Vaughan and Cole, Barker, p. 314 (Mexico).
1939. *Operculinoides palmarealensis* Barker, p. 314 (Mexico).
1939. *Operculinoides vicksburgensis* Vaughan and Cole, Barker, p. 318 (Mexico).
1941. *Operculinoides bullbrooki* Vaughan and Cole, p. 44 (Trinidad).
1941. *Operculinoides semmesi* Vaughan and Cole, Vaughan and Cole, p. 50 (Trinidad).
1941. *Operculinoides semmesi ciperensis* Vaughan and Cole, p. 51 (Trinidad).
1941. *Operculinoides antiguensis* Vaughan and Cole, Vaughan and Cole, p. 53 (Trinidad).
1944. *Operculinoides antiguensis* Vaughan and Cole, Cole, p. 40 (Florida).
1944. *Operculinoides dius* (Cole and Ponton), Cole, p. 42 (Florida).
1944. *Operculinoides vicksburgensis* Vaughan and Cole, Cole, p. 49 (Florida).
1945. *Operculinoides vicksburgensis* Vaughan and Cole, Cole, p. 26 (Florida).
1957*b*. *Amphistegina bullbrooki* (Vaughan and Cole), Cole, p. 37 (Trinidad).
1958*a*. *Operculinoides dia* (Cole and Ponton), Cole, p. 198 (general).

Remarks.—This species has been discussed in detail recently (Cole, 1958*a*, p. 198-200). Mexican specimens from two localities are illustrated, and a median section of a topotype of *O. vicksburgensis* is introduced for comparison.

One suite of these Mexican specimens (Pl. 34, figs. 3, 6) had been identified previously as *O. semmesi.* These illustrations should be compared with Barker's (1939, pl. 19, figs. 1-6) illustrations and with the type illustrations (Vaughan and Cole, 1936, pl. 37, figs. 11-13). The other suite of Mexican specimens (Pl. 34, figs. 4, 9) had been identified previously as *O. antiguensis.*

Barker (1939, p. 314) in discussing similar suites of Mexican specimens had written ". . . . since both have the same range in Mexico and have not yet been found to occur in the same localities, suggesting that the differences may be due to local changes in environment." Study of various species of *Operculinoides* (Cole, 1958*a*, *b*) demonstrates that this suggestion of Barker was correct.

The increase in height of the chambers in the final volution in *O. dia* is variable and is an individual rather than a specific character. This may be observed if the illustrations (Pl. 34, fig. 2; pl. 5, fig. 3, Cole, 1945; pl. 19, figs. 8, 9, Barker, 1939; and Pl. 34, fig. 9) are compared. All of these sections with the exception of Pl. 34, fig. 9 were made from specimens identified previously as *O. vicksburgensis.*

Operculinoides floridensis (Heilprin) Pl. 33, fig. 2

1885. *Nummulites floridensis* Heilprin, p. 321 (Florida).
1918. *Nummulites davidensis* Cushman, p. 98 (Panama).
1919. *Nummulites antillea* Cushman, p. 51 (St. Bartholomew).
1921*b*. *Operculina cookei* Cushman, p. 127 (Georgia).
1921*b*. *Operculina vaughani* Cushman, p. 128 (Georgia).
1921*b*. *Operculina ocalana* Cushman, p. 129 (Alabama).
1921*b*. *Operculina floridensis* (Heilprin), Cushman, p. 130 (Florida).
1925. *Operculina oliveri* Cushman, p. 298 (Mexico).
1927. *Operculina cushmani* Cole, p. 23 (Mexico).
1927. *Operculina bartschi plana* Cole, p. 23 (Mexico), not *O. bartschi plana* Cushman, 1921*a*.
1932. *Operculina floridensis* (Heilprin), Rutten and Vermunt, p. 238 (Curaçao).
1932. *Operculina curasavica* Rutten and Vermunt, p. 239 (Curaçao).
1935. *Operculina vaughani* Cushman, Gravell and Hanna, p. 334 (Texas).
1936. *Operculina vaughani* Cushman, Vaughan, p. 250 (Louisiana).
1939. *Operculinoides jennyi* Barker, p. 315 (Mexico).
1939. *Operculinoides ocalanus* (Cushman), Barker, p. 316 (Mexico).
1939. *Operculinoides ocalanus minor* Barker, p. 317 (Mexico).
1939. *Operculinoides oliveri* (Cushman), Barker, p. 318 (Mexico).
1939. *Operculinoides vaughani* (Cushman), Barker, p. 319 (Mexico).
1941. *Operculinoides curasavicus* (Rutten and Vermunt), Cole, p. 29 (Florida).

1941. *Operculinoides floridensis* (Heilprin), Cole, p. 30 (Florida).
1941. *Operculinoides ocalanus* (Cushman), Cole, p. 31 (Florida).
1941. *Operculinoides ocalanus* (Cushman), Vaughan and Cole, p. 38 (Trinidad).
1941. *Operculinoides soldadensis* Vaughan and Cole, p. 40 (Trinidad).
1944. *Camerina guayabalensis* Cole, p. 39 (Florida), pl. 1, fig. 4; pl. 5, fig. 17; pl. 7, figs. 2, 9, 11, 21; pl. 17, fig. 5; *not* pl. 17, fig. 4 which is *Camerina striatoreticulata* (L. Rutten)
1944. *Operculinoides floridensis* (Heilprin), Cole, p. 43 (Florida).
1944. *Operculinoides jennyi* Barker, Cole, p. 45 (Florida).
1944. *Operculinoides nassauensis* Cole, p. 47 (Florida).
1944. *Operculinoides ocalanus* (Cushman), Cole, p. 48 (Florida).
1945. *Operculinoides cookei* (Cushman), Cole, p. 104 (Florida).
1945. *Operculinoides vaughani* (Cushman), Cole, p. 104 (Florida).
1947. *Nummulites* (*Operculinoides*) *soldadensis* (Vaughan and Cole), Cizancourt, p. 517 (Cuba).
1949. *Operculinoides floridensis* (Heilprin), Cole, p. 270 (Panama Canal Zone).
1949. *Operculinoides ocalanus* (Cushman), Cole, p. 270 (Panama Canal Zone).
1952. *Operculinoides floridensis* (Heilprin), Cole, p. 9 (Panama Canal Zone).
1952. *Operculinoides ocalanus* (Cushman), Cole, p. 10 (Panama Canal Zone).
1952. *Operculinoides vaughani* (Cushman), Cole, p. 11 (Panama Canal Zone).
1956*a*. *Operculinoides cushmani* (Cole), Cole, p. 214 (Jamaica).
1956*a*. *Operculinoides jennyi* Barker, Cole, p. 220 (Jamacia).
1958*a*. *Operculinoides floridensis* (Heilprin), Cole, p. 182 (general).

Remarks.—This species is not discussed as Cole (1958*a*, p. 182) has already considered it in detail. However, another vertical section of a specimen previously identified as *O. jennyi* Barker (Cole, 1956*a*, p. 220) is illustrated (Pl. 33, fig. 2). This species was separated from other Jamaican specimens by Cole because of the large size of the embryonic chambers. However, it is obvious that it is the same as Jamaican specimens (Cole, 1958*a*, pl. 21, figs. 5, 10, 13; pl. 22, figs. 4, 5) which are identical with *O. antillea.* As *O antillea* is a synonym of *O. floridensis, O. jennyi* is placed in the synonomy of *O. floridensis.*

Operculinoides gravelli Cole

1944. *Operculinoides gravelli* Cole, p. 44 (Florida).

Remarks.—This small species from the middle Eocene of Florida requires more study. As far as can be determined at present, it seemingly is a distinct species.

Operculinoides panamensis (Cushman)

1918. *Nummulites panamensis* Cushman, p. 98 (Panama Canal Zone).
1941. *Operculinoides panamensis* (Cushman), Vaughan and Cole, p. 46 (Trinidad).
1952. *Operculinoides panamensis* (Cushman), Cole, p. 10 (Panama Canal Zone).
1958*a*. *Operculinoides panamensis* (Cushman), Cole, p. 200 (Panama Canal Zone).

Operculinoides trinitatensis (Nuttall)

1928. *Operculina trinitatensis* Nuttall, p. 102 (Trinidad).
1935. *Camerina jacksonensis* Gravell and Hanna, p. 331 (Texas).
1939. *Camerina jacksonensis* Gravell and Hanna, Barker, p. 324 (Mexico).
1939. *Camerina jacksonensis globosa* Barker, p. 324 (Mexico).
1941. *Operculinoides kugleri* Vaughan and Cole, p. 42 (Trinidad).
1941. *Operculinoides trinitatensis* (Nuttall), Vaughan and Cole, p. 47 (Trinidad).
1942. *Camerina jacksonensis* Gravell and Hanna, Cole, p. 26 (Florida).
1945. *Camerina jacksonensis* Gravell and Hanna, Cole, p. 101 (Florida).
1952. *Operculinoides jacksonensis* (Gravell and Hanna), Cole, p. 9 (Panama Canal Zone).
1952. *Operculinoides kugleri* Vaughan and Cole, Cole, p. 9 (Panama Canal Zone).
1952. *Operculinoides trinitatensis* (Nuttall), Cole, p. 11 (Panama Canal Zone).

Operculinoides willcoxi (Heilprin) Pl. 33, figs. 1, 3-12

1882. *Nummulites willcoxi* Heilprin, p. 321 (Florida).
1921*b*. *Operculina willcoxi* (Heilprin), Cushman, p. 129 (Florida).
1928*a*. *Operculina nummulitiformis* L. Rutten, p. 941 (Peru).
1929. *Operculinella sabinensis* Cole, p. 62 (Texas).
1932. *Operculina nummulitiformis* L. Rutten, M. G. Rutten and Vermunt, p. 239 (Curaçao).
1935. *Camerina moodybranchensis* Gravell and Hanna, p. 322 (Texas).
1936. *Operculinoides advenus* Vaughan and Cole, p. 489 (Mexico).
1937. *Operculinella nummulitiformis* (L. Rutten), Vaughan, p. 159 (Ecuador).
1938. *Operculinoides sabinensis* (Cole), Cole, p. 38 (Florida).
1939. *Operculinoides willcoxi* (Heilprin), Barker, p. 309 (Mexico).
1939. *Operculinoides nummulitiformis* (L. Rutten), Barker, p. 310 (Mexico).
1939. *Operculinoides prenummulitiformis* Barker, p. 311 (Mexico).
1939. *Camerina moodybranchensis* Gravell and Hanna, Barker, p. 323 (Mexico).
1941. *Camerina moodybranchensis* Gravell and Hanna, Cole, p. 28 (Florida).
1941. *Operculinoides willcoxi* (Heilprin), Cole, p. 32 (Florida).
1942. *Camerina moodybranchensis* Gravell and Hanna, Cole, p. 27 (Florida).
1945. *Camerina moodybranchensis* Gravell and Hanna, Cole, p. 102 (Florida).
1945. *Operculinoides willcoxi* (Heilprin), Cole, p. 106 (Florida).
1952. *Operculinoides moodybranchensis* (Gravell and Hanna), Cole, p. 10 (Panama Canal Zone).
1958*a*. *Operculinoides sabinensis* (Cole), Cole, p. 196 (general).

Remarks.—Cole (1952, p. 10) recognized that *Camerina moodybranchensis* Gravell and Hanna (1935, p. 332) possesses all the characteristics of *Operculinoides willcoxi* (Heilprin). However, at that time he did not combine the two species. Study of abundant specimens from Panama referred to *O. moodybranchensis* and specimens from Florida assigned to *O. willcoxi* prove that only one species can be recognized.

Additional specimens from Florida (Pl. 33, figs. 1, 3, 4, 9, 12) and from Panama (Pl. 33, figs. 5, 10, 11) are illustrated to show the characteristics of *O. willcoxi*. Measurements of these specimens follow:

MEASUREMENTS OF OPERCULINOIDES WILLCOXI (HEILPRIN)

Median Sections

Locality	4.5 miles west of Williston, Fla.			108, Panama	
Specimen	Pl. 33, fig. 9	Pl. 33, fig. 12	*	Pl. 33, fig. 11	Pl. 33, fig. 10
Height mm.	3.15	3.2	3.5	3.5	3.35
Width mm.	2.8	2.8	3.1	2.97	3.25
Embryonic chambers: Diameters of initial chamber μ	100x130	100x130	175x175	130x140	90x90
Diameters of second chamber μ	100x160	70x120	70x170	75x130	50x90
Distance across both chambers μ	250	200	250	230	140
Whorls	4¼	4½	4¾	4¾	5½
Chambers in first volution	10	10	10	8	11
Chambers in final volution	27	27	26	36	29
Total number of chambers	85	87	95	110	119

*See: pl. 1, fig. 12, Bull. Amer. Paleont., v. 35, No. 147, 1953

Transverse Sections

Locality	4.5 miles west of Williston, Fla.				108, Panama
Specimen	Pl. 33, fig. 3	Pl. 33, fig. 1	Pl. 33, fig. 4	*	Pl. 33, fig. 5
Height mm.	2.65	3.1	3.3	3.1	3.25
Thickness at center mm.	0.85	0.95	1.05	1.1	1.17
Surface diameter of umbonal plug μ	350	500	400	350	400

*See: pl. 2, fig. 2, Bull. Amer. Paleont., v. 35, No. 147, 1953

In the upper Eocene specimens, which on detailed study cannot be separted from Floridian specimens assigned to *O. willcoxi*, have been named *Operculina nummulitiformis* (L. Rutten) from Peru and Curaçao, *Operculinoides advenus* Vaughan and Cole, *O. nummulitiformis,* and *Camerina moodybranchensis* from Mexico, and *O. moodybranchensis* from Panama. Thus, this species is widely distributed in the upper Eocene.

Recently, Cole (1958*a*, p. 182) demonstrated that numerous previously recognized species should be combined with *O. floridensis* (Heilprin), a species with a stratigraphic range from upper middle Eocene into the upper Eocene. Therefore, the possibility was investigated that certain previously recognized species from the upper middle Eocene might be in reality *O. willcoxi.* The questionable species were *O. sabinensis* (Cole) from the upper middle Eocene of Texas and Florida, and *O. prenummulitiformis* Barker from the Guayabal formation of Mexico. Cole (1958*a,* p. 196) has demonstrated that these two species should be combined under the name *O. sabinensis.*

In the original description of *O. sabinensis* (Cole, 1929) the statement was made "This species is nearest *O. willcoxi* (Heilprin) from the Ocala limestone, but differs in the smaller number of chambers, smaller size and greater wave-like appearance of the sutures." At that time such criteria appeared to be valid for separating species. However, as it has been demonstrated by studies of numerous specimens of a given species from a single population that wide variation may occur in size, thickness and number of chambers, such criteria are no longer valid.

Therefore, *O. sabinensis* is believed to be a synonym of *O. willcoxi,* and this species ranges from upper middle Eocene into the upper Eocene. The specimens previously called *O. sabinensis* from the upper middle Eocene and those from the upper Eocene which were named *O. moodybranchensis* were found in clastic sediments, whereas the specimens from the upper Eocene which were called *O. willcoxi* were recovered from limestone.

As Cole (1958*a*, p. 191) demonstrated with regard to *O. floridensis,* specimens from limestone normally are larger and have thicker revolving walls. This same development occurs in the specimens here assigned to *O. willcoxi* so that minor structural and size differences between populations are the result of ecological control rather than genetic development.

Nummulites costaricensis K. Palmer (1923, Bull. Amer. Paleont., v. 10, No. 40, p. 9) may be another synonym of this species. The types were glued to slides, but during the years intervening, as the glue dried, they dropped from the slides and were lost. So far, Dr. Palmer, Director of the Paleontological Research Institution, has not been able to find additional specimens in the collection.

Genus **Operculina** d'Orbigny, 1826

Operculina mariannensis Vaughan

1928. *Operculina mariannensis* Vaughan, p. 158 (Florida).
1936. *Operculina tuberculata* Vaughan and Cole, p. 488 (Mexico).
1939. *Operculinoides tuberculata* (Vaughan and Cole), Barker, p. 319 (Mexico).
1939. *Operculina barkeri* Vaughan and Cole, p. 538 (new name for *O tuberculata* preoccupied by *O. costata tuberculata* Douvillé, 1911).
1945. *Operculina barkeri* Vaughan and Cole, Cole, p. 107 (Florida).
1945. *Operculina mariannensis* Vaughan, Cole, p. 108 (Florida).

Remarks.—If the illustrations of specimens called *O. mariannensis* and *O. barkeri* are compared, they show a continuous series. Specimens called *O. barkeri* have more and heavier beading, otherwise there is no difference.

Genus **Paraspiroclypeus** Hanzawa, 1937

Paraspiroclypeus chawneri (D. K. Palmer) Pl. 34, figs. 1, 5, 8, 10, 11

1934. *Camerina chawneri* (D. K. Palmer), p. 261 (Cuba).

Remarks.—Although the type illustrations of this species are excellent, additional illustrations are given to demonstrate the internal structures.

Genus **Heterostegina** d'Orbigny, 1826

Remarks.—For a key to the American Eocene and Oligocene species of *Heterostegina*, see: Cole, 1957*a*, p. 326.

Genus **Spiroclypeus** H. Douvillé, 1905

Spiroclypeus bullbrooki Vaughan and Cole

1941. *Spiroclypeus bullbrooki* Vaughan and Cole, p. 54 (Trinidad).

Remarks.—This is the only described American species of a genus which is well represented and wide-spread in the Miocene (Tertiary *e*) of the Indo-Pacific region.

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PLATES

EXPLANATION OF PLATE 32

Figure		Page
1-16.	**Camerina striatoreticulata** (L. Rutten)	265

1-4, 11-13. Transverse sections, x 20.

5-7, 10, 15, 16. Median sections, x 12.5, except 5, x 20.

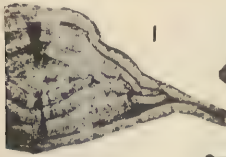
14. Part of the median section, x 40, illustrated as fig. 10, to show the Y-shaped processes on the proximal ends of the chamber walls (first volution to the upper left beyond the embryonic chambers).

1-3, 5. From locs. 17*a* and 17*b*, collected by the late Alfred Senn, from brown limestones between the coast and a vertical limestone cliff on the northern slope of the promontory separating Anse des Cayes and Baie de St. Jean, St. Bartholomew, Fr. W. I.

6-8. From loc. V-109, coll. H. R. Versey, from a marl pit at the foot of Swanswick Hill, Trelawny, Jamaica, B. W. I.

10, 12-15. From a depth of 258-265 feet from the United Brotherhood of Carpenters and Joiners well (W-448), located about two miles N. Lakeland, Polk Co., Fla.

11, 16. From a quarry north of Florida highway 5-A, 5.2 miles NW. Mayo, Lafayette Co., Fla., coll. H. Naegeli.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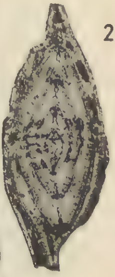
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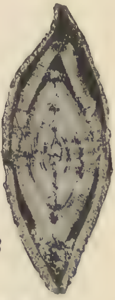
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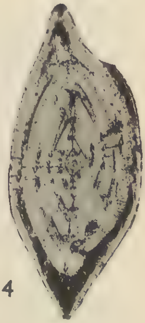
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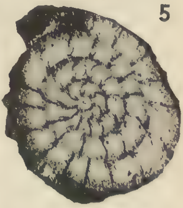
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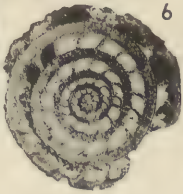
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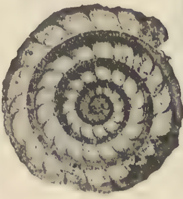
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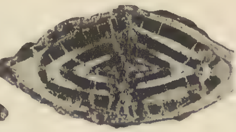
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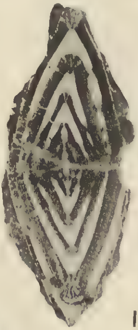
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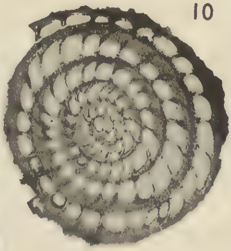
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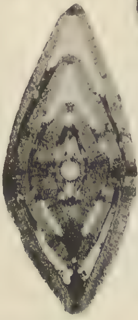
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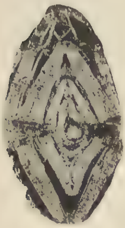
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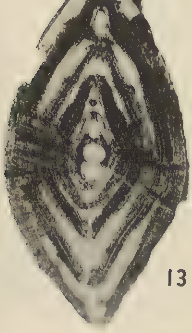
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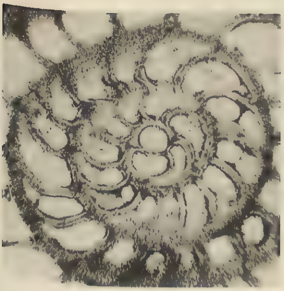
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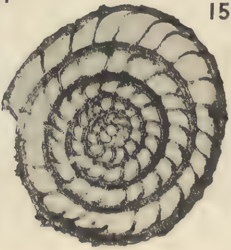
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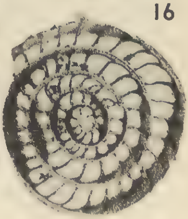
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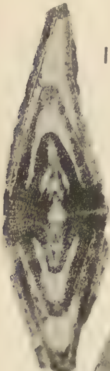
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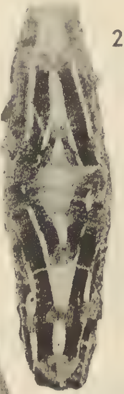
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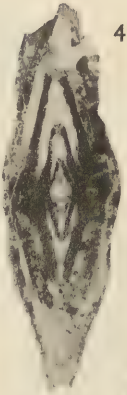
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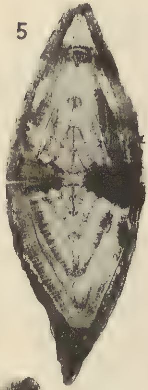
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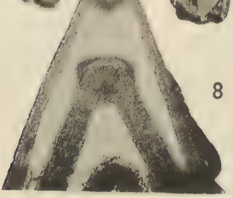
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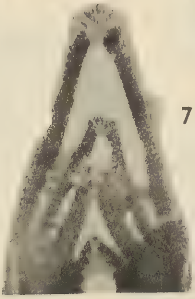
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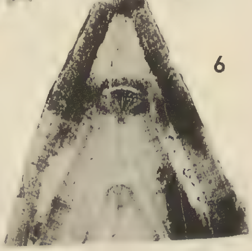
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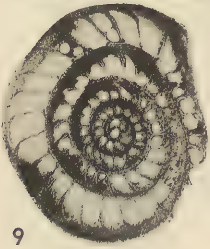
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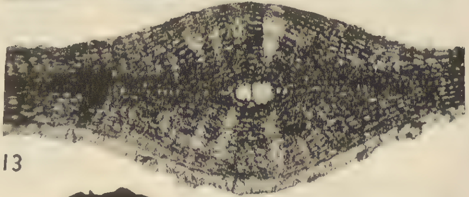
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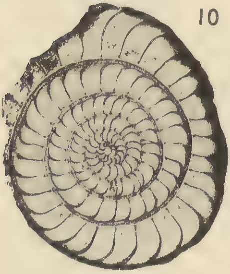
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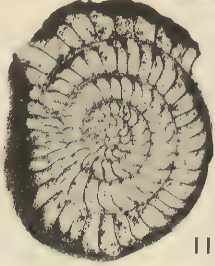
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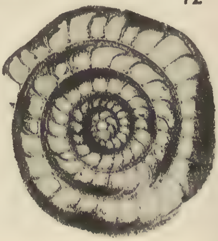
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EXPLANATION OF PLATE 33

Figure Page

1, 3-12. **Operculinoides willcoxi** (Heilprin) 273

1, 3-5. Transverse sections, x 20.

6-8. Parts of transverse sections, x 40, to show apertures and marginal cord. 6, upper part of fig. 5; 7, lower part of fig. 3; 8, upper part of fig. 2, pl. 2, Bull. Amer. Paleont., v. 35, No. 147, 1953.

9-12. Median sections, x 12.5.

2. **Operculinoides floridensis** (Heilprin) 271

Transverse section, x 40.

13. **Asterocyclina asterisca** (Guppy) 261

Part of a transverse section, x 40.

1, 3, 4, 7-9, 12. From 4.5 miles west of Williston, Levy Co., Fla., coll. W. S. Cole.

2. From loc. V-109 coll. H. R. Versey, from a marl pit at the foot of Swanswick Hill, Trelawny, Jamaica, B. W. I.

5, 10, 11. From loc. 108, collected by T. F. Thompson and W. P. Woodring, from road to Madden Airfield, 0.5 miles NE. Calzada Larga, Madden Basin, Panama.

13. From loc. K. 2854, coll. H. Kugler, from Soldado Rock, Trinidad.

EXPLANATION OF PLATE 34

Figure Page

1, 5, 8, 10, 11. **Paraspiroclypeus chawneri** (D. K. Palmer) 276

1. Part of the transverse section, x 40, illustrated as fig. 8, to show the marginal cord and the vacuoles developed in the spiral sheet.

5, 8. Transverse sections, x 12.5.

10. Median section, x 12.5.

11. Part of the median section, x 40, illustrated as fig. 10 to show the embryonic chambers and the canal within the chamber walls.

2-4, 6, 9. **Operculinoides dia** (Cole and Ponton) 270

2. Median section, x 20, previously illustrated as fig. 2, pl. 5 (Cole, 1945), of *O. vicksburgensis* Vaughan and Cole, 1936.

3. Transverse section, x 20, of a Mexican specimen similar to certain topotypes of *O. semmesi* Vaughan and Cole, 1936.

4. Transverse section, x 20, of a Mexican specimen of the kind originally called *O. antiguensis* Vaughan and Cole, 1936.

6. Median section, x 20, of a Mexican specimen of the same kind as the one shown as fig. 3.

9. Median section, x 20, of a Mexican specimen of the same kind as the one shown as fig. 4.

7. **Operculinoides cojimarensis** (D. K. Palmer) 270

Transverse section, x 20, of an umbonally inflated specimen with a narrow flange.

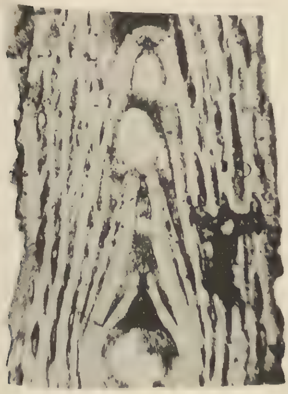
1, 5, 8, 10, 11. Topotypes from 2 km. S. from Km. post 5.5 on the Cardenas-Varadero road, thence 800 m. NW. to trail, thence 400 m. W., Matanzas Prov., Cuba; coll. the late Mrs. D. K. Palmer.

2. Near Byram, Miss.

3, 6. From Arbol Grande, near Tampico, Tamaulipas, Mex., coll. W. S. Cole.

4, 9. From road cut on the road to the Chairrel Club, Tampico, Tamaulipas, Mex., coll. W. S. Cole.

7. Two km. SW. of Cojimar on the Hershey railroad, Habana Prov., Cuba; collected by the late Mrs. D. K. Palmer.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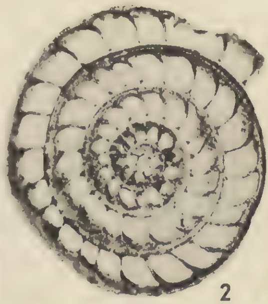
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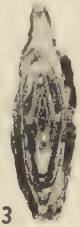
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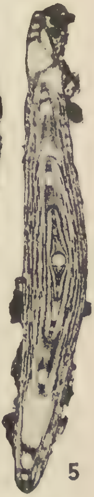
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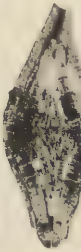
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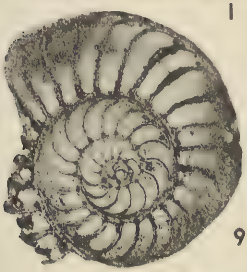
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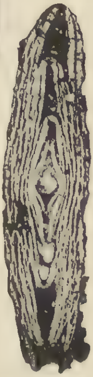
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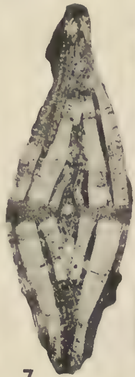
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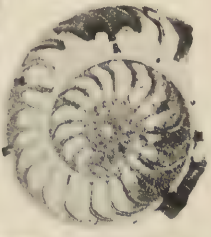
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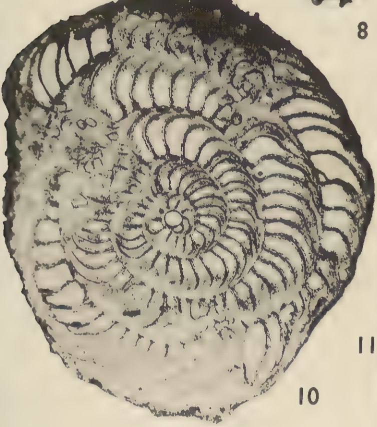
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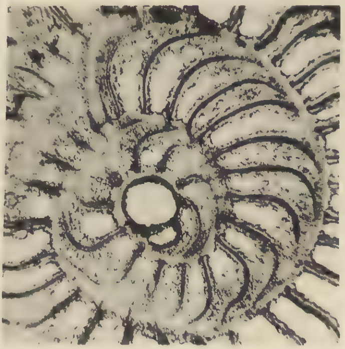
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THE AMERICAN SPECIES OF ASTEROPHYLLITES, ANNULARIA, AND SPHENOPHYLLUM

By
Maxine Langford Abbott
University of Cincinnati

December 30, 1958

Paleontological Research Institution
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THE AMERICAN SPECIES OF *ASTEROPHYLLITES*, *ANNULARIA*, AND *SPHENOPHYLLUM*

Maxine Langford Abbott
University of Cincinnati

ABSTRACT

Organ genera based on roots, stems, leaves, and fructifications of both herbaceous and arborescent sphenopsids are common in the collections of Pennsylvanian fossils. In a large part the sterile foliage may be referred to *Asterophyllites, Annularia,* and *Sphenophyllum,* and less frequently to *Lobatannularia* or *Equisetites.* There is considerable taxonomic confusion concerning these genera and this paper is an attempt 1) to re-evaluate North American species of *Asterophyllites, Annularia,* and *Sphenophyllum;* 2) to present means of their identification; 3) to determine the geological range and geographical distribution; and 4) to present some new morphological data concerning the mucro, sheath, epidermal pattern, stomata, and hairs which have been obtained by using transfer methods.

Asterophyllites and *Annularia* are foliage shoots of probable calamitean affinity represented by branched or simple, articulated, delicate stems bearing whorls of leaves at each articulation. These genera are similar in that they have leaves which are usually linear-lanceolate, uninerved, and more or less conspicuously united at the base. Distinctive features of the leaves of the two genera include the type of lateral margins, the width, and the position of the leaves in the whorl with relation to the axis. In *Asterophyllites* the leaves are of equal length, are usually cupped around the axis, while in *Annularia* the leaves, which are equal in length in some species and unequal in others, radiate from the node.

Determination of the individual species within the two genera is based upon details of the width-length ratio, number of leaves in a whorl, shape of the leaf, and size and position of the widest portion of the leaf. It is necessary to use a combination of characters rather than a single feature in order to separate one species from another in either genus.

The leaves of *Sphenophyllum* occur in verticils or whorls usually of six leaves at the articulations of the axes and do not alternate with those of the verticil below but are superposed.

The leaf varies from cuneate to elongate-oval, from more or less entire with pointed or blunt teeth to laciniate or to deeply lobed or filamentous. The kind and degree of dissection of the leaves may vary greatly from the apex to the base of the plant, but the overall pattern of leaf dissection is consistent for the species.

The leaves of each verticil form the same angle to the axis and give a radial symmetry and are usually oriented so that they lie in a plane parallel to the axis. Most of the species bear verticils of leaves of equal length but in some they are in pairs of unequal length.

Sphenophyllum is readily distinguished from *Asterophyllites* and *Annularia* by the venation of the leaf. In *Sphenophyllum* one vein enters the base of the leaf and undergoes one to eight dichotomies before the resulting veinlets terminate at the distal margin in the lobes or teeth.

It has been found in North America that 1) *Asterophyllites* includes four species namely. *Ast. charaeformis* (Sternberg) Geoppert, 1884, *Ast. equisetiformis* (Schlotheim) Brongniart, 1828, *Ast. grandis* (Sternberg) Geinitz, 1855, and *Ast. longifolius* (Sternberg) Brongniart, 1828; 2) *Annularia* includes ten species, namely, *Ann. acicularis* (Dawson) White, 1900, *Ann. aculeata* Bell, 1944, *Ann. disteris* Bell, 1944, *Ann. galioides* (Lindley and Hutton) Kidston, 1891, *Ann. latifolia* (Dawson) Kidston, 1886, *Ann. mucronata* Schenk, 1883.

Ann. radiata (Brongniart) Sternberg, 1825, *Ann. sphenophylloides* (Zenker) Gutbier, 1837, *Ann. stellata* (Schlotheim) Wood, 1860, and *Ann. vernensis* (Arnold) Abbott, 1958; and 3) *Sphenophyllum* includes 18 species, namely, *Sph. angustifolium* (Germar) Geoppert, 1848, *Sph. arkansanum* White, 1936, *Sph. cornutum* Lesqquereux, 1870, *Sph. cuneifolium* (Sternberg) Zeiller, 1880, *Sph. emarginatum* Brongniart, 1828, *Sph. fasciculatum* (Lesquereux) White, 1899, *Sph. gilmorei* White, 1929, *Sph. lescurianum* White, 1899, *Sph. longifolium* (Germar) Geinitz, 1843, *Sph. majus* Bronn, 1835, *Sph. oblongifolium* (Germar and Kaulfuss) Unger, 1850, *Sph. obovatum* Sellards, 1908, *Sph. tenerrimum* (Ettingshausen) Stur, 1887, *Sph. tenue* White, 1900, *Sph. tenuifolium* Fontaine and White, 1880, *Sph. thoni* Mahr, 1868, *Sph. trichomatosum* Stur, 1887, and *Sph. verticillatum* (Schlotheim) Zeiller, 1885.

ACKNOWLEDGMENTS

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INTRODUCTION

Organ genera based on roots, leaves, and fructifications of both herbaceous and arborescent sphenopsids are common in the collections of Pennsylvanian fossils. In a large part the sterile foliage may be referred to *Asterophyllites, Annularia,* or *Spenophyllum* and less frequently to *Lobatannularia* or *Equisetites.* In the process of describing the fossil flora of the Upper Freeport (No. 7) Coal in Athens County, southeastern Ohio, it was found necessary to review the reported North American species of these genera, as there is considerable taxonomic confusion concerning them.

This paper is an attempt 1) to re-evaluate the North American species of the genera *Asterophyllites, Annularia,* and *Sphenophyllum;* 2) to present means of their identification; 3) to determine the geological range and geographic distribution; and 4) to present some new morphological data concerning the mucro, sheath, epidermal pattern, stomata, and hairs which have been obtained by using transfer methods.

Two transfer techniques (Abbott, M. L., 1950; Abbott, R. E., and M. L. Abbott, 1952) were employed with excellent results in this study. The entire compression is removed from the rock, washed in hydrofluoric acid and water, and studied under transmitted or reflected light. Small specimens were permanently mounted in balsam on standard slides.

Asterophyllites (Pl. 35, fig. 4) and *Annularia* (Pl. 35, fig. 6) are genera of probable calamitean affinity represented only in the collections by articulated, branched or unbranched delicate stems bearing whorls of leaves at each articulation or node. These genera are similar in that they have leaves which are usually linear-lanceolate, uninerved and more or less conspicuously united at the base by a sheath which is sometimes not recognized as such. Distinguishing features of the leaves of the two genera include the width-length ratio and position of the leaves in the whorl with relation to the axis. In *Asterophyllites* the margins of the leaves are essentially straight or parallel, the leaves thus tapering gradually to an acute apex. The width-length ratio is usually great (Chart 1), averaging 1:10 and may be as high as 1:100. In only one species, *Asterophyllites charaeformis,* is it less than 1:10. The general effect is that of a linear or acicular leaf. In *Annularia* (Chart 2), on the other hand, the leaves are lanceolate to obovate or spatulate, so that the position of the maximum width is an important diagnostic character. When the maximum width occurs near the apex, the leaves taper to a point or mucro (a short prolongation of the midvein). When the maximum width is near or at the middle, the leaves taper much more gradually. In *Asterophyllites* the leaves, which are of equal length, are usually cupped around the axis (Pl. 35, fig. 4); that is, they form an angle of approximately 60° with the axis and then bend abruptly upwards to lie parallel to the axis. The compressed sheath, which is frequently difficult to observe but is always present to a greater or lesser degree, may appear elliptical in outline. In *Annularia,* the leaves, which are equal in length (Pl. 35, fig. 7) in some species and unequal in others (Pl. 35, fig. 5), radiate from the node. Here the sheath appears circular in outline. These leaf orientations are not always constant, as *Asterophyllites* leaves have been observed which were flattened in the plane of the axis and *Annularia* leaves cupped around the axis. These are exceptions and are probably due to diagenesis of the sediments.

Separation of the individual species within the two genera is based upon the details of the width-length ratio, numbers of leaves in a whorl (5-50), shape of the leaf, and the position of the widest portion of the leaf. It is necessary to use a combination of characters rather than a single feature in order to separate one species from another in either genus.

The leaves of *Sphenophyllum* (Pl. 44, figs. 66-69) also occur in verticils of usually six leaves at the nodes or articulations of the axes, and do not alternate with those in the verticils above and below, but are superposed. *Sphenophyllum* is readily distinguished from *Asterophyllites* and *Annularia* by the venation of the leaf. One vein enters the base of the leaf and undergoes one to eight dichotomies before the resulting veinlets terminate at the distal margin, often in the teeth or lobes. The first bifurcation of the single vein may be immediate on entering the leaf (Charts 3-4), or it may be traverse 1-2 mm. before dichotomising. In those species in which the leaves are broadly obovate rather than cuneate-truncate, it is difficult to determine where the distal margin ends and lateral margins begin. Some of the veins do not reach the apex of the distal margin, but end along the lateral margins.

The leaves of each verticil stand out at the same angle to the axis, giving a radial symmetry, and are usually oriented so that they lie in a plane parallel to the axis. Most of the species bear verticils of leaves of equal length (Pl. 44, fig. 66), but some bear leaves in pairs of unequal length (Pl. 44, fig. 69). In the anisophyllous species, the leaves are bilaterally symmetrically paired in three pairs in each verticil (Pl. 38, fig. 30). Each pair may be a different length or only one pair may be shorter than the other two. In either case, the shortest pair is directed toward the base of the plant and the other two pairs nearly at right angles to the axis leaving a gap of 90-180° in the upper part of the verticil. Usually there are six leaves in a verticil, but there may be eight or nine (Pl. 38, fig. 29). As many as eighteen leaves have been reported by European authors, but this high number has not been reported in any North American species.

The shape of the leaf varies from cuneate to broadly ovate. Most species are cuneate and the distal margins are straight or nearly so; however, some species are characterized by rounded distal margins giving an ovate shape to the leaves. The general appearance of the leaves varies with the nature of the dissection of the distal margin. Some species are undivided and the distal margin is set with pointed or blunt teeth (Pl. 38, fig. 32); others are laciniated or fringed (Pl. 38, fig. 39), while still others are deeply lobed or even filamentous (Pl. 37, fig. 22). The kind and degree of dissection of the leaf may vary greatly depending on its position on the axis, whether near the apex or the base of the plant, but the overall pattern of leaf dissection is consistent for the species. For example, in the upper portions of the axis, the distal margin may be entire or toothed, while in leaves progressively lower on the same axis the margin is more and more deeply dissected until the ultimate in dissection results in a filamentous leaf (Pl. 37, fig. 22). The reverse of this is seen in at least one of the species, *Sph. angustifolium,* and to some degree in *Sph. fasciculatum* (Pl. 37, fig. 27), in which the most deeply dissected leaves occur at the apices of axes and less dissected to entire leaves toward the base.

The lateral margins of the leaves of *Sphenophyllum* are usually straight (Pl. 38, fig. 30), but in some species they are strongly concave (Pl. 38, fig. 32), while in others they are convex (Pl. 38, fig. 39).

The cells of both the adaxial (Pl. 38, fig. 44) and abaxial (Pl. 38, figs. 37-42) epidermis are relatively thin-walled, elongated in the direction of the long axis of the leaf, with the lateral walls somewhat thicker than the more or less inclined undulate end walls. The size and shape of the cells and the thickness of the cell walls vary within a species to such an extent that they may not be used for specific determination. Stomata, (Pl. 38, figs. 44-45) observed only on the abaxial epidermis, have two kidney-shaped sunken guard cells surrounded by approximately three to five irregular accessory cells.

Minute hairs, some of 135 mu long, occur on the margins of the leaves of *Sph. angustifolium* (Pl. 38, figs. 40, 41; Pl. 44, fig. 65), are simple, and appear to be an extension of an epidermal cell. Much longer marginal hairs up to 1 mm. in length have been observed on an isolated whorl of leaves doubtfully referred to *Sph. cuneifolium.* Marginal hairs on the leaves of that species, however, have not otherwise been observed or known on other species.

The axes are usually slender and flexuous (Pl. 44, fig. 66), but some are quite stout and rigid (Pl. 44, fig. 66). Branching in some species is sparse but in others is frequent, the branches occurring singly, opposite, or whorled at the nodes. The internodes are from 1 to 80 mm. long, but most commonly are about 1 cm. The axes are seldom over 5 mm. wide, although the largest known is more than 1 cm. wide and the smallest branches may be only a third of a millimeter wide.

TAXONOMIC TREATMENT

KEY TO THE GENERA

I. Leaves falcate, linear or linear-lanceolate, uninerved, united basally by a sheath.
    A. Leaves overlapping the upper internode only and cupping the axis, leaf margins parallel, area of leaf attachment apparently elliptical .... I. *Asterophyllites*
    AA. Leaves radiating from the node, more or less covering both upper and lower internodes, leaf margins convex, area of leaf attachment apparently circular........................ II. *Annularia*

II. Leaves cuneate to broadly ovate, one vein enters the base of the leaf and undergoes one to several dichotomies .... III. *Sphenophyllum*

I. [1]**ASTEROPHYLLITES** Brongniart, 1822

Asterophyllites Brongniart, 1872, Classification, Memoires Museum Histoire naturelle, VIII, p. 210.
Schlotheimia Sternberg, 1823, Flora der Vorwelt, I, fasc. 2, p. 31.
Myriophyllites Sternberg, 1824, Flora der Vorwelt, I, fasc. 3, p. 39.
Bornia Sternberg, 1825, Flora der Vorwelt, fasc. 4, p. xxviii.
Bruckmannia Sternberg, 1825, Flora der Vorwelt, I, fasc. 4, p. xxix.
Volkmannia Sternberg, 1825, in part, Flora der Vorwelt, fasc. 4, p. xxix.
Bechera Sternberg, 1825, Flora der Vorwelt, I, fasc. 4, p. xxx.
Hippurites Lindley and Hutton, 1836, Fossil Flora, 3:105, London.
Calamites Ettingshausen, 1851, in Haidinger's Naturwissenschaftliche Abh., IV, 1:72.
Calamocladus Schimper, 1869, Traité, 1:323.
Asterophyllum Schimper, 1880, in Zittel, Handbuch Paleontologie, II, Lief. 2, p. 175.

The leaves occur in verticils at the nodes, forming an angle of approximately 60° with the axis. They are falcate to linear with an acuminate apex; fused basally into a sheath. The leaves are uninerved, with the vein occupying one-fourth to one-half the width of the leaf. In compression the nodal area to which these leaves are attached is usually conspicuously elliptic. The leaves are of equal length with a width-length ratio averaging 1:10, are openly spread apart, and are either as long as the internode or overlap one or more whorls above. The leaves are dorsi-ventral; the abaxial epidermis is composed of about eight to ten rows of elongate cells on either side of the midvein. The lateral cell walls are straight to slightly undulate; the end walls are straight and are variously at right angles or inclined. The adaxial epidermis is composed of elongate cells with strongly undulate to nearly straight lateral walls; the end walls are straight and inclined or tapering. Stomata occur occasionally on the adaxial epidermis but are more frequent and scattered on the abaxial epidermis. Each is surrounded by two kidney-shaped guard cells, and the aperture is approximately parallel to the midvein.

---

[1] From Jongmans, Fossilium Catalogus, II. Plantae, Pars 4, 1914.

KEY TO THE SPECIES

A. Leaves 30-40 in a whorl, averaging 7-10 cm. long; width-length ratio 1:30-1:100 ....4. *Ast. longifolius*
AA. Leaves 4-20 in a whorl
  a. Leaves 12-20 in a whorl; up to 2 cm. long; width-length ratio 1:15 ....2. *Ast. equisetiformis*
  aa. Leaves 4-8 in a whorl
    b. Leaves 4-5 in a whorl; not more than 2.5 mm. long; width-length ratio 1:5 ....1. *Ast. charaeformis*
    bb. Leaves usually 8 in a whorl; up to 1 cm. long; width-length ratio 1:10 ....3. *Ast. grandis*

1. **Asterophyllites charaeformis** (Sternberg) Goeppert

Pl. 35, fig. 2; Pl. 48, figs. 85, 86; Chart 1

Bechera charaeformis Sternberg, 1825, Flora der Vorwelt, I, 4:30, p. xxx, pl. 55, figs. 3, 5.
Asterophyllites charaeformis (Sternberg), Goeppert, 1844, in Wimmer, Flora von Schlesien Preuss, und Oster. anth., Breslau, p. 198.
Asterophyllites gracilis Lesquereux, 1860, Second Report of a Geol. Reconnaisance of the Middle and South Counties of Arkansas, p. 310, pl. 2, figs. 4, 4a.
Asterophyllites ? minutus Andrews, 1875, Ohio Geol. Report, II, Geol. and Paleont., p. 424, pl. 51, figs. 4, 4a.

Additional references.—Jongmans (1914, 96-98, bibliographic), Bell (1940, 129, pl. 10, fig. 3; 1944, 103, pl. 63, fig. 2; pl. 68, fig. 1 in part; pl. 70, fig. 1).

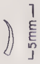
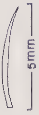
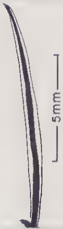
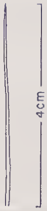
CHART I	ASTEROPHYLLITES CHARAEFORMIS GOEPPERT 1884	ASTEROPHYLLITES EQUISETIFORMIS BRONGNIART 1828	ASTEROPHYLLITES GRANDIS STERNBERG 1825	ASTEROPHYLLITES LONGIFOLIUS STERNBERG 1825
NO OF LEAVES PER WHORL	4 - 10	12 - 20	16 - 20	30 - 40
LEAF FORM	falcate widest at base	linear-lanceolate widest at middle	linear-falcate widest at base	linear widest at middle
LEAF MARGINS	I margin concave I margin convex	convex	I margin concave I margin convex	straight
LEAF LENGTH	1.5 - 3mm	6 - 20 mm; 1.5 - 4 cm	5 - 10mm	2.5 - 14 cm
WIDTH-LENGTH RATIO	1:4; 1:6	1:12 ; 1:20	1:10 ; 1:15	1:50 ; 1:100
VARIATION OF LEAVES IN WHORL	none	none	none	none
INCLINATION OF LEAVES TO AXIS	90°	30°-90°	90°	45°
MEDIAN VEIN	1/2 width of leaf	1/4-1/2 width of leaf	1/2 width of leaf	1/2 width of leaf
DIAGRAM				

Chart 1. Species of *Asterophyllites.*

Stratigraphic range.—Pottsville to lower Allegheny.

The leaves, 4 to 10 in each verticil, are spread apart, may be as long as the internode or may slightly overlap the whorl above. They are attached to the axis at an angle of approximately 90° but curve abruptly upwards parallel to the axis. While the leaves vary in length from 3 mm. on the larger branches to 1.5-2.5 mm. on the ultimate branches, the width, which is approximately 0.5 mm. at the base, with a midvein of about 0.2 mm., is essentially the same.

The larger axes are 8 mm. broad with slightly raised flat continuous ribs, with internodes up to 3 cm. long. Much smaller axes or ultimate branches (Pl. 35, fig. 2) are found more frequently. They vary from 0.5 to 4.0 mm. in width, are longitudinally striated, and have internodes from 15 mm. long near the juncture with the next higher rank axis to 2 mm. long near the tip.

Horizon and distribution[2].—Canada: *Nova Scotia,* Pictou Coalfield, Pictou and Stellarton Series—lower Allegheny (cited by Bell, 1940); *Northern Nova Scotia,* Cumberland group—Pottsville (cited by Bell, 1944), Riversdale group—lower Pottsville (cited by Bell, 1944). United States: *Arkansas,* Males Coal Bank—lower Allegheny (cited by Lesquereux, 1860); *Ohio,* Rushville, Perry County—Pottsville (cited by Andrews, 1875, the original of *Ast. ? minutus,* and WVA-C); *Indiana; Georgia,* Dade; *Alabama,* Woodworth Coal Mine—no exact locality or horizon is available for the last three localities (cited by Lesquereux, 1880, 1884).

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[2] The species cited have been described and figured in sufficient detail so that their identity is beyond reasonable doubt. The following abbreviations have been used to designate the localities of the specimens in the citations under the individual species:—

US—United States National Museum, Washington, D. C.
CINC—Botany and Bacteriology Department, University of Cincinnati, Cincinnati, Ohio.
CINC-T—Abbott Collection, Cincinnati, Ohio.
OU—Botany Department, Ohio University, Athens, Ohio.
WVA-G—Geology Department, University of West Virginia, Morgantown, West Virginia.
WVA-S—West Virginia Geological Survey, Morgantown, West Virginia.
WVA-C—A. T. Cross Collection, Morgantown, West Virginia.
CAS—Department of Geology, California Academy of Sciences, Golden Gate Park, San Francisco, California.
AJM—A. J. Miklausen Collection, West Allegheny Senior High School, Oakdale, Pennsylvania.
HBL—Harvard Biological Laboratories, Harvard University, Cambridge, Mass.

2. **Asterophyllites equisetiformis** (Schlotheim) Brongniart, 1828, Pl. 35, fig. 4; Pl. 36, figs. 12, 15, 19, 20; Pl. 39, figs. 46, 47, 49-51; Pl. 43, fig. 63; Pl. 47, fig. 78

Casuarinites equisetiformis Schlotheim, 1820, Petrefactenkunde, Gotha, p. 397.

Asterophyllites equisetiformis (Schlotheim), Brongniart, 1828, Prodrome, Paris, p. 159, 176.

Asterophyllites trinervis Dawson, 1866, Geol. Soc. London, Jour., 22:152, pl. 13, fig. 90.

Annularia erectifolius Andrews, 1875, Geol. Rept. Ohio, Paleontology, 2:425, pl. 49, fig. 3.

Other references.—Jongmans (1914, 105-115, bibliographic; 1923, 757-758, bibliographic), Jongmans (1935, 407, 410, pl. 32, fig. 103), Bell (1938, 86, pl. 87, figs. 3, 4; pl. 88, fig. 1), Janssen (1939, 88, fig. 71), Bell (1940, 128), Bell (1944, 103, pl. 70, fig. 2; pl. 71, figs. 1, 3), Arnold (1949, 183, pl. 17, figs. 2, 4-5).

Stratigraphic range.—Pottsville through the Allegheny.

The leaves of both the larger and the ultimate axes are in verticils of 12 to 20 (the number varying and often indeterminate because of preservation factors). The leaves are linear-lanceolate with nearly parallel margins and a sharply pointed apex. The lower leaves on the axis are attached at approximately a right angle (fig. 46) and at about the middle curve upward; the intermediate and upper leaves are attached at successively smaller angles, the smallest angle being approximately 30° (Pl. 35, fig. 4; Pl. 39, fig. 46). The upper leaves are less curved and are essentially straight for the most of their length.

The leaves on the larger axes are approximately 15 mm. long, while the leaves on the branches of these axes are 6-20 mm. long and 0.5-1.0 mm. wide. In both, a single vein occupies from one-fourth to one-half the width of the leaf.

In their ascending progression, the leaves become smaller and more appressed and/or erect until the verticils overlap, are compact and cupulate at the apices (Pl. 39, figs. 47, 49-51). Due to the extreme shortening of the internodes, the stem has an overall "paint brush" appearance. Neither spores nor sporangial structures, which would indicate that this portion of the axis was fertile, have been found. Plate 39, figure 49 (young plant ?) and its enlargement at figure 50 shows the grouping of the "paint brush" apices.

The adaxial epidermis of this species shows eight to ten rows of cells on either side of the vein which are elongated in the direction of the long axis of the leaf. The lateral walls (Pl. 36, fig. 12) are straight to slightly undulate and the end walls are straight to inclined. The abaxial epidermis (Pl. 36, fig. 19; Pl. 43, fig. 63) shows cells with strongly undulate to nearly straight lateral walls and straight to inclined and tapering end walls. Stomata occur occasionally on the adaxial surface (Pl. 36, figs. 19, 20; Pl. 43, fig. 63) but are more frequent on the abaxial surface (Pl. 36, fig. 12). Each is surrounded by two kidney-shaped guard cells (Pl. 36, fig. 20); accessory cells are absent. The aperture of the stoma is approximately parallel to the midvein. The stomata do not appear to be arranged in any pattern but are scattered over the surface.

The midvein, although incompletely preserved in transferred specimens, possesses seven to eight elongate parallel elements (Pl. 36, fig. 19 ; Pl. 43, fig. 63), all of which are approximately the same width and have the same lateral wall thickness. Pitting or other markings indicative of cell types have not been observed.

The epidermal cells of the leaf sheath decrease in size toward the node. A series of short cells with greatly thickened walls (Pl. 36, fig. 15) occupies the angle formed by the union of two leaves. No stomata have been found in the sheath area.

Two, possibly more, ranks of branches occur, the larger are 45 cm. long and bear as many as eighteen internodes. These latter are up to 4 cm. long and 1.5 cm. wide. They are striated to conspicuously ribbed, the ribs or ridges being 0.2-0.3 mm. wide with grooves correspondingly wide. A larger axis bears at each node at least two lateral branches and a verticil of leaves (2.7 cm. long); the complete lateral branches may be up to 14.5 cm. long and bear as many as fifteen whorls of leaves (2 cm. long). The internodes of the lateral branches are 1.3-0.3 cm. long and decrease successively and proportionately in length and width from the base to the apex. The nodes on both ranks of branches are usually conspicuously enlarged and on the ultimate branches 0.5-1.0 mm. wider than the internodes to which they are adjacent. The nodal line is usually straight but in some cases is slightly inclined.

Asterophyllites equisetiformis is usually represented in collections by ultimate branches, with internodes averaging 1 cm. long and nodes with leaf whorls whose leaves average about 1.2 cm. long (Pl. 39, fig. 46).

Four exceptionally large axes, bearing these typical ultimate branches, have been studied. One was collected from the Cherokee shale, Clinton, Missouri (Lacoe Collection, U. S. National Museum). This axis is 45 cm. long and has nine internodes, those at the base are 4 cm. long and those in the upper part 3 cm. long. At each node this axis bears both leaves (2.7 cm. long) and complete lateral branches (14.5 cm. long). The lateral branches have internodes 13 mm. long at the base and 9 mm. long in the upper part. They bear fourteen whorls of leaves, the basal ones being 17 mm. long.

The second specimen, from the Brookville clay near McArthur, Ohio, (Abbott Collection, No. 3575), is 35 cm. long with 18 internodes. These are 5 mm. wide in the basal region and 3.5 cm. long and 2 mm. wide and 2.5cm. long in the upper part. This axis bears at almost every node (incompletely preserved) leaves which are 1.5 cm. long and complete lateral branches 11 cm. long.

The third specimen, from the Upper Freeport near Kimberly, Ohio, (Abbott Collection, No. 5606) has six internodes. These are 3.9 cm. long and 1.5 cm. wide in the lower part of the axis and 3.5 cm. long and 0.4 cm. wide in the upper part.

Occasionally, axes with extremely shortened and thickened internodes (Pl. 39, figs. 47, 49-51), probably young branches or plants, bear lateral branches whose internodes are also shortened and thickened. On these specimens, the leaf whorls on the lateral branches enclose several superior internodes with their unopened whorls which give these lateral branches a "paint brush" appearance. The absence of spores and sporangial structure indicate that this portion of the axis was not fertile.

Figure 50 (Plate 39), an enlargement of part of Figure 49, shows a series of lateral "paint brush" structures attached at about a 30° angle in whorls around an axis. One of these lateral elements bears basal leaves which are almost as long as the usual leaf (Pl. 39, fig. 46). They are close together, appressed, and enclose and overlap the shortened superior internodes and almost all of the superior leaf whorls. In this respect, the structure is essentially budlike in character.

In Figure 51 (Plate 39), the internodal length of the axis bearing the budlike structure is about the same as that in Figure 49, although the budlike structures appear more mature. They form a wider angle with the stem (about 90°) and are more open because the leaves are not so closely appressed. The leaves which occur at the nodes with the lateral "buds" are more robust, and they are essentially parallel to the axis.

Figure 47 (Plate 39) shows a detached lateral "bud" which appears to be somewhat more mature than those in Figure 51. The more or less mature basal leaves are as long as the basal ones of the open verticils of Figure 46. The internodes are about 3 mm. long, much longer than those of the lateral "buds" of Figure 51, and the basal leaves enclose only about one-half of the "bud."

Horizon and distribution.—Canada: *Nova Scotia,* Pictou Coalfield, Pictou-Stellarton series—middle Allegheny (cited by Bell, 1940); *Northern Nova Scotia,* Cumberland group—Pottsville (cited by Bell, 1944), Riversdale group—Pottsville (cited by Bell, 1944) Cansco group—lower Pottsville (cited by Bell, 1944), Sydney Coalfield from below the Tracey to the top of the Morien series—Allegheny (cited by Bell, 1938). United States: *Ohio,* Rushville, Perry County—Pottsville (cited by Andrews, 1875, the original of *Ann. erectifolius*), Kimberly, Athens County—uppermost Allegheny (CINC-T), McArthur, Vinton County—lower Allegheny (CINC-T); *Michigan,* Cycle "A"—middle Pottsville (cited by Arnold, 1949); *Illinois,* Mazon Creek—Allegheny, Morris—Allegheny (cited by Noé, 1925); *Missouri,* Clinton, Henry County—lower Allegheny (US), Gilkerson's Ford and Owens Coalbank—Allegheny (cited by White, 1899); *Pennsylvania,* Cannelton and Gate vein—Allegheny (cited by White, 1889), Tipton, Blair County—Allegheny (CINC); *Kentucky,* Perry County, Blue Diamond Mine—Pottsville (CINC).

3. **Asterophyllites grandis** (Sternberg) Geinitz, 1855 Chart 1

Bechera grandis Sternberg, 1825, Flora der Vorwelt, Regensburg, I, 4:42, p. xxx, pl. 49, fig. 1.

Asterophyllites grandis (Sternberg), Geinitz, 1855, Die versteinerungen der Steinkohlenformation in Sachsen, pp. 8-9, pl. 17, figs. 4-5.

Other references.—Jongmans (1914, 124-128, bibliographic; 1923, 759, bibliographic; 1935, 407, pl. 32, fig. 102), Bell (1944, 104, pl. 67, fig. 5; pl. 69, fig. 4; pl. 70, figs. 3-4; pl. 72, figs. 1-4; pl. 74, fig. 5; pl. 75, fig. 1).

Stratigraphic range.—Pottsville to middle Allegheny.

The diffuse, linear falcate leaves, 5-10 mm. long, 0.5-0.75 mm. wide, occur in verticils of 16 to 20 on the larger axis and verticils of 8 to 10 on the ultimate branches. Leaves borne on the larger axes are shorter than the internodes; leaves borne on the smaller axes are longer than the internodes, their apices reaching the succeeding higher nodes. The midvein is relatively strong, occupying approximately one-half the width of the leaf and is elevated and striated.

The largest axes, with leaves no longer present, are 12-20 mm. wide and internodes 3-4 cm. long. The branches of these axes are 3-8 mm. wide with internodes 5-20 mm. long and are finely longitudinally ribbed or striated. They vary from 2 to 8 cm. in overall length and their internodes, which are usually 2 mm. long, may be up to 4 mm. long and 0.5-1.0 mm. wide.

Horizon and distribution.—Canada: *Northern Nova Scotia,* Cumberland group—Pottsville (cited by Bell, 1944), Riversdale group—Pottsville (cited by Bell, 1944). United States: *Iowa,* near Bloomington (cited by Goeppert, 1851); *Illinois,* Morris Coal—Allegheny (cited by Lesquereux, 1880); *West Virginia,* locality unknown—upper part of Kanawa series—lower Pottsville (cited by Jongmans, 1935); *Ohio,* near Albany—middle Allegheny (CINC-T); *Rhode Island,* horizon and locality unknown (cited by Lesquereux, 1880).

4. **Asterophyllites longifolius** (Sternberg) Brongniart, 1828,
Pl. 40, fig. 53; Pl. 42, fig. 60; Chart 1

Bruckmannia longifolia Sternberg, 1825, Flora der Vorwelt, Regensburg, I, 4:45, p. xxix, pl. 58, fig. 1.

Asterophyllites longifolius (Sternberg), Brongniart, 1828, Prodrome, Paris, pp. 159, 176.

Other references.—Jongmans (1914, 133-137, bibliographic; 1923, 760, bibliographic), Read (1934, 83, pl. 16, fig. 8), Bell (1938, 86, pl. 92, fig. 5), Janssen (1939, 88, fig. 72), Bell (1940, pl. 3, fig. 5).

Stratigraphic range.—Pottsville to upper Allegheny.

The linear leaves number 30 to 40 in a verticil and form an angle of 45° with the axis and curve upward (Pl. 40, figs. 53, 60). They are 2.5-14.0 cm. long, 0.5-1.5 mm. wide, and form a sheath at the node 1 mm. in height. The verticils are 1.5 to 3 times longer than the internode and sometimes overlap several nodes. The striated carinate midvein is conspicuously shown only on the adaxial surface of the leaf and averages 0.5 mm. in width. The striated axis has internodes 12-35 mm. long and 2-7 mm. wide. Branching has not been observed on this species.

Bell, in 1940, described *Ast. longifolius* forma *striata* from the Pictou Coalfield based on prominent longitudinal striation on both the axes and leaves. The midveins of the leaves were not preserved, but the description agrees with the species in all other respects. Specimens of *Ast. equisetiformis* from various horizons also show these striae on occasion. These striations coincide with the parallel lateral walls of the cells of the epidermis; that is, the lateral walls of the cells which are aligned parallel to the long axis of the leaf, appear as more or less prominent continuous lines unbroken by the end walls of the cells.

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Harbour, between the Bouthillier and Harbour coal seams—in the lower one-half of the *Ptychocarpus unitus* zone—upper Allegheny (cited by Bell, 1938), Pictou Coalfield, Cumberland group—upper Pottsville (cited by Bell, 1940). United States: *Illinois,* Mazon Creek—Allegheny (cited by Janssen, 1939); *Pennsylvania,* Pittston, Wilkesbarre, Cannelton—Allegheny (cited by Lesquereux, 1880); *Missouri,* Henry County, near Clinton—lower Allegheny (CINC), Gilkerson's Ford, Pitcher's Coal bank, Owens Coalbank—Allegheny (US); *Ohio,* Athens County, Kimberly—uppermost Allegheny (CINC-T); *Colorado,* Mosquito Range, Weber formation—Pottsville (cited by Read, 1934).

II. [3] **Annularia** Sternberg, 1823

Casuarinites Schlotheim, 1820, Petrefactenkunde, p. 397, Gotha.
Annularia Sternberg, 1823, Flora der Vorwelt, I, fasc. 2, pp. 28, 31, 32, 36.
Bornia Sternberg, 1825, Flora der Vorwelt, I, fasc. 4, p. xxviii.
Trochophyllum Wood, 1860, Acad. Nat. Sci. Philadelphia, Proc. p. 438.

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[3] From Jongmans, Fossilium Catalogus, II, Plantae, Pars 2, 1936.

The leaves occur in verticils at and radiate from the nodes. They are lanceolate to ovate or spatulate, uninerved, and are basally fused into a sheath. In compression the nodal area to which these leaves are attached is usually conspicuously circular. A single vein occupies one-seventh to one-half the width of the leaf. The leaves are equal in length in some species and unequal in others, have a width-length ratio of 1:8 on the average, and are seldom longer than the internode. The leaves are dorsi-ventral; the abaxial epidermis over the midvein is composed of five or six rows of thin-walled cells elongated parallel to the midvein, with end walls more or less at right angles to the lateral walls. There are no stomata in this area. Between the midvein and the margin of the leaf, the abaxial epidermis is composed of thin-walled cells with essentially straight walls. The cells are elongated toward the margin of the leaf at less than a right angle from the midvein. Stomata are quite crowded between the midvein area and the margin of the leaf and not confined to a groove or narrow band. Each stoma is surrounded by two guard cells and two accessory cells. The guard cells are inconspicuous, small, sunken, and often not visible. The accessory cells are conspicuously kidney-shaped. Simple hairs occur on the abaxial epidermis. The adaxial epidermis is composed of cells similarly arranged as those of the abaxial epidermis, except that the surface is devoid of stomata.

KEY TO THE SPECIES

A. Leaves widest at the middle
  a. Leaves 6-15 mm. long
    b. Leaves 8-18 in a whorl, of equal length, width-length ratio 1:10-1:15 ....5. *Ann. acicularis*
    bb. Leaves 10-14 in a whorl, of equal length, width-length ratio 1:6-1:12 ....11. *Ann. radiata*
  aa. Leaves 1.5-4 mm. long, with blunt apex, width-length ratio 1:3-1:5 ....8. *Ann. galioides*
AA. Leaves widest above the middle
  c. Leaves spatulate and strongly mucronate
    d. Leaves 12-22 in a whorl, of approximately equal length; the whorl occasionally acentric with the lower leaves shorter, width-length ratio 1:6-1:8 .... 13. *Ann. sphenophylloides*

dd. Leaves 10-24 in a whorl, lateral leaves much longer, width-length ratio 1:3-1:7 ....10. *Ann. mucronata*
cc. Leaves oblanceolate
e. Leaves 6-12 in a whorl, less than 1 cm. long
f. Leaves averaging 5-7 mm. long
g. Width-length ratio 1:5 ....9. *Ann. latifolia*
gg. Width-length ratio 1:10 ....14. *Ann. vernensis*
ff. Leaves 1.5-5 mm. long
h. Leaves 3.5-4 mm. long, width-length ratio 1:4-1:7 .... 6. *Ann. aculeata*
hh. Leaves 1.5-5 mm. long, width-length ratio 1:6........................ 7. *Ann. asteris*
ee. Leaves 16-32 in a whorl, 2.5 cm. long, width-length ratio 1:5-1:10 ....12. *Ann. stellata*

5. **Annularia acicularis** (Dawson) White, 1900 Chart 2

Asterophyllites acicularis Dawson, 1862, Geol. Soc. London, Quart. Jour., 18:310, pl. 13, figs. 16a, b.
Asterophyllites lenta Dawson, 1871, Geol. Sur. Canada, p. 29, pl. 5, fig. 60.
Asterophyllites laxa Dawson, 1878, Acadian Geology, 3d ed., p. 539, London.
Annularia acicularis (Dawson), White, 1900, United States Geol. Sur., 20th Ann. Rept., 2:898.
?Annularia recurva Matthew, 1906, Royal Soc. Canada, Trans., 12:128, pl. 2, figs. 1-3.
Asterophyllites spp. Stopes, 1914, Geol. Sur. Canada, Mem. 41:20, pl. 4, fig. 5.

Other references.—Dawson (1868, 537, figs. 194H, H_1 (not fig. H_2); 1871, 28, pl. 5, figs. 54a-c, ?57 (not figs. 55-56); 1888, 82, fig. 31H (not fig. H_2), Matthew (1906, 127, pl. 5, fig. 1, (not figs. 2-3); p. 122, pl. 5, figs. 6, 7; 1910, 94), Jongmans (1914, 6, bibliographic), Bell (1944, 101, pl. 58, figs. 2, 5; pl. 60, fig. 6; pl. 63, fig. 3; pl. 64, fig. 5; pl. 65, fig. 2; pl. 69, fig. 5).

Stratigraphic range.—Lower Pottsville to lower Allegheny.

The leaves number 8 to 18 in a verticil and are 6-15 mm. long, 0.5-1.0 mm. wide, with the maximum width approximately median. They are lanceolate, with the lateral ones slightly longer than those more or less parallel to the axis.

The verticils are flattened in the plane of the axis. Although the leaves of a verticil generally radiate from the node, the leaves,

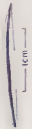
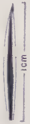
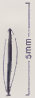
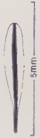
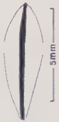
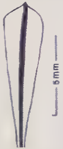
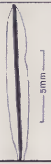
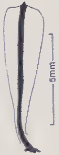
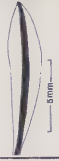
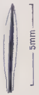
CHART 2	ANNULARIA ACICULARIS (DN)D.WHITE 1900	ANNULARIA ACULEATA BELL 1944	ANNULARIA ASTERIS BELL 1944	ANNULARIA GALIOIDES (L. & H.)KIDSTON 1891	ANNULARIA LATIFOLIA (DN)KIDSTON 1886	ANNULARIA MUCRONATA SCHENK 1883	ANNULARIA RADIATA (BGT)STERNB. 1825	ANNULARIA SPHENOPHYLLOIDES (ZN.)GUTBIER 1837	ANNULARIA STELLATA (SCH.)WOOD 1860	ANNULARIA VERNENSIS (ARNOLD) ABBOTT
NO. OF LEAVES PER WHORL	8 - 18	5 - 12	8 - 12	8 - 12	7 - 12	10 - 24	8 - 20	10 - 20	13 - 32	about 12
LEAF FORM	lanceolate	linear-lanceolate	linear-lanceolate	oblanceolate	oblanceolate	spatulate	linear-lanceolate	spatulate	oblanceolate	lanceolate
LEAF APEX	acutely pointed	acutely pointed geniculate	acuminate	blunt to rounded	mucronate rounded	distinctly mucronate	acutely pointed	mucronate broadly rounded	mucronate obtusely pointed	acute
LEAF MARGINS	widest at middle tapers apically and basally	parallel tapers to a point above middle	nearly parallel tapers apically and basally	widest above middle tapers basally	widest above middle tapers basally	widest above middle tapers basally	widest at middle tapers apically and basally	widest above middle tapers basally	widest above middle tapers apically and basally	widest above middle tapers basally
LEAF LENGTH	6-15mm	1-10mm	1.5-5mm	1.5-5mm	7-10mm	4-25mm	7-30mm	3-12mm	14-75mm	5mm
WIDTH-LENGTH RATIO	1:12 ; 1:15	1:4 ; 1:7	1:6	1:3 ; 1:5	1:5	1:3 ; 1:7	1:6 ; 1:12	1:6 ; 1:8	1:5 ; 1:10	1:5
VARIATION OF LEAVES IN WHORL	lateral leaves longer	equal	equal	approx. equal	lateral leaves longer	lateral leaves longer	equal	lateral leaves longer	lateral leaves longer	equal
INCLINATION OF LEAVES TO AXIS	in plane of axis rarely cupped	in plane of axis up-curved in young stems	in plane of axis	in plane of axis	in plane of axis	in plane of axis	in plane of axis	in plane of axis	in plane of axis	about 90°
MEDIAN VEIN	1/4 width of leaf	1/3-1/2 width of leaf	1/3 width of leaf	1/4 width of leaf	1/7 width of leaf	1/5 width of leaf	1/4-1/5 width of leaf	1/5 width of leaf	1/3-1/5 width of leaf	1/3 width of leaf
DIAGRAM										

Chart 2. Species of *Annularia.*

especially in the verticils near the tip of the branch, are arched and have a "cupped" aspect.

The midvein, which is marked by longitudinal striae, occupies about one-fourth of the width of the leaf. The epidermis, although not well preserved in available specimens, apparently has the same cell pattern as that of the adaxial surface of the leaves of *Ann. stellata* (Pl. 36, fig. 9).

Matthew (1906) included *Ast. lenta* and *Ast. laxa* of Dawson under *Ast. lentus*. He did not mention the sheath or midvein in his study of *Ast. lentus*. In the same paper he later transferred the *Ast. acicularis* of Dawson to *Annularia*. Bell (1944) concluded *Ast. lentus* is identical with *Ann. acicularis*. Specimens from Harlan County, Kentucky, support Bell's conclusion. Bell (1944) also suggested that *Ann. recurva* probably was synonymous with *Ann. acicularis*.

Based on relatively few specimens of isolated leaf verticils, many authors, including Jongmans in his "Fossilium Catalogus", consider *Ann. acicularis* synonymous with *Ann. radiata*. Studies of collections from the United States and Canada demonstrate that *Ann. acicularis* is quite distinct from *Ann. radiata*. The width-length ratio of *Ann. acicularis* is 1:12 to 1:15, while that of *Ann. radiata* is 1:6 to 1:12. The basic form of the leaf of *Ann. acicularis* is linear, whereas that of *Ann. radiata* is linear-lanceolate. The lateral leaves of *Ann. acicularis* are longer than the others in a whorl; those of *Ann. radiata* are equal.

Horizon and distribution.—Canada: *Northern Nova Scotia*, Riversdale group—lower Pottsville (cited by Bell, 1944); Cumberland group—upper Pottsville (cited by Bell, 1944). United States: *Pennsylvania,* Lincoln Mine and Pottsville Gap, Sewanee zone—Pottsville (cited by White, 1900); *Kentucky,* Harlan County, Yokum Mine—Pottsville (CINC); *Ohio,* McArthur, Vinton County—lower Allegheny (CINC-T).

6. **Annularia aculeata** Bell, 1944 Chart 2

Annularia aculeata Bell, 1944, Geol. Sur. Canada, Mem. 238: 101, pl. 60, figs. 3, 4; pl. 62, fig. 2; pl. 63, fig. 4; pl. 65, figs. 1, 4; pl. 66, fig. 1, 3; pl. 68, figs. 1 (in part), 2, 3, 4; pl. 69, figs. 1, 2, 3, 6; pl. 74, figs. 4, 7.

Other references.—None.

Stratigraphic range.—Pottsville.

The leaves, 5 to 12 in a verticil, are linear-lanceolate, acutely pointed at the apex and not constricted at the base. They are 1-10 mm. long and 0.25-0.75 mm. wide, of equal length, and usually flattened in the plane of the axis, although occasionally the leaves of the ultimate axes curve upward and due to an unusual split of the shale matrix the axes appear to be asterophyllitean in longitudinal section, especially when only two leaves are visible.

The midvein occupies one-third to one-half the width of the leaf.

The ultimate branches are lax, flexuous, opposite, and attached both obliquely and nearly at right angles to larger branches. The internodes of the ultimate branches are 1-3 mm. long and 0.5 mm. wide, while the internodes of the larger axes are 7-10 mm. long and 0.5 mm. wide.

In transfer preparations, the cells are found to be longitudinally oriented over the rather wide midvein, from which the cells curve away toward the leaf margin just as they do in *Ann. stellata.*

Variation in the size and the number of the leaves in a verticil is rarely found in other species of *Annularia.* The five leaves, and the total diameter of the verticil may be no more than 3 mm. wide, with 3-4 mm. common. On the axes bearing the ultimate branches, however, the verticils may be composed of nine to ten leaves with a diameter of up to 20 mm.

This great variation in the size and the number of leaves in a verticil immediately separates *Ann. aculeata* from *Ann. galoides,* which also is more robust in appearance and whose leaves gradually diminish in size. *Ann. asteris* has more leaves in a verticil than *Ann. aculeata* and the gradual decrease in the size of its leaf whorls separates it from *Ann. aculeata.*

Similarly between *Ann. aculeata* and *Ann. acicularis* lies only in the lax appearance of the leaf whorls. *Ann. aculeata* has 5 to 12 linear-lanceolate leaves of equal length in a verticil, while *Ann. acicularis* has 8 to 17 lanceolate leaves of unequal length in a verticil. The leaves of *Ann. aculeata* are never longer than 1 cm., while those of *Ann. radiata* may be up to 3 cm. long.

Horizon and distribution.—Canada: *Northern Nova Scotia,* Cumberland group—upper Pottsville; Riversdale group—Pottsville (cited by Bell, 1944; CINC-T). Known only from Canada.

7. **Annularia asteris** Bell, 1944 Pl. 35, fig. 7; Pl. 39, fig. 48; Pl. 40, fig. 54; Pl. 49, figs. 88, 89; Chart 2

Annularia minuta Brongniart, 1828, Prodrome, pp. 155, 176 (*nomen nudum*), Paris.

Annularia minuta Wood, 1866, American Phil. Soc., Trans., 13:347, pl. 8, fig. 2.

Annularia sp. Arnold, 1934, Univ. Michigan, Mus. Paleont., Cont., 4:187, pl. 1, figs. 2, 4.

Annularia asteris Bell, 1944, Geol. Sur. Canada, Mem. 238: 102-103, pl. 67, fig. 3; pl. 68, fig. 5.

Other references.—None.

Stratigraphic range.—Pottsville to lower Dunkard.

The leaves, 8 to 12 in a verticil, are all of equal length, and linear-lanceolate, with sides more or less parallel. The apices are acuminate, the bases slightly constricted. The leaflets on the larger axes are up to 5 mm. long and slightly less than 0.5 mm. wide; those on the ultimate axes are 1.5-2.5 mm. long and 0.25-0.4 mm. wide (figs. 7, 48). The midvein occupies approximately one-third of the leaf (Chart 2).

The largest known North American specimen is an axis (designated first order for convenience) which has internodes 6 cm. long and 7-8 mm. wide, and the nodes are enlarged. It bears two lateral branches (second order) at each node with internodes near the base 2 cm. long and 3 mm. wide. These branches bear leaves 5 mm. long and two branches (third order) at each node 5 cm. long with seven whorls of leaves. The internodes of these latter are 5 mm. long and 1 mm. wide near the base. The branches of the third order also bear two lateral branches (fourth order) 2.5 cm. long and five whorls of leaves. The nodes of the branches of the third and fourth orders are not noticeably enlarged.

All of the branches are opposite and distichous and are attached at wide angles. The internodes are rather short and the adjacent verticils of leaves do not overlap. The general effect is an appearance of sparse leaf verticils and lax branches. In this respect, the plant is much different from *Ann. galioides*. In *Ann. asteris,* six whorls of leaves occur over a span of 4 cm. of the axis, while in *Ann. galioides* five whorls of leaves occur in a 2 cm. span of the axis. The leaves are wider in proportion to length in *Ann. galioides* and more linear-lanceolate in *Ann. asteris,* as a comparison of figure 52, with figure 54, Plate 40, will show.

Brongniart listed an *Annularia* in his Prodrome without figures or description, as *Ann. minuta.* Wood (1886) stated "as there appears to be a good deal of obscurity hanging over this species, M. Brongniart, as far as I can learn, never having published either description or figure, I give for an *Annularia** from the coal-fields of West Virginia, to which the name may be applied." In the footnote he states further "Prof. Lesquereux informs me that it is the same species as the plant found by him in the Gate vein, Pottsville, and mentioned by him in his catalogue under the name. *A. minuta,* Brongn."

Lesquereux (1884) redescribed Wood's species and other specimens of the same form from the Gate vein near Pottsville, Pennsylvania, as *Ann. minuta.* Since the original name *Ann. minuta* Brongniart, 1828, is a *nomen nudum,* the reference to it by Wood and Lesquereux cannot be maintained. A study of the original material collected by Wood has revealed that it is identical with *Ann. asteris,* and the species *Ann. minuta,* therefore, is reduced to synonymy.

Horizon and distribution.—Canada: *Northern Nova Scotia,* Cumberland group—Pottsville (cited by Bell, 1944). United States: *Ohio,* McArthur, Vinton County—lower Allegheny (CINC-T); Jackson, Jackson County—Pottsville (OU, CINC-T); Pomeroy, Meigs County—Monongahela (OU); *Michigan,* Grand Ledge, Cycle "B"—Pottsville (cited by Arnold, 1949); *Pennsylvania,* near Pottsville, Gate vein—Pottsville (US); *West Virginia,* Brown's Mill, Monongalia County—Washington (WVA-G); Worley, Monongalia County—Dunkard (WVA-G).

8. **Annularia galioides** (Lindley and Hutton) Kidston, 1891
Pl. 40, fig. 52; Chart 2

Asterophyllites galioides Lindley and Hutton, 1832, The Fossil Flora of Great Britain, London, 1:79, pl. 25, fig. 2.

Annularia microphylla Sauveur, 1848, Végétaux fossils des terrains houillers de la Belgique, pl. 69, fig. 6.

Annularia emersoni Lesquereux, 1880, Second Geol. Sur., Pennsylvania, Rept. Progress P, 1:50-51.

Annularia sphenophylloides var. *minor* Lesquereux, 1880, Second Geol. Sur., Pennsylvania Rept. Progress P, Atlas, pl. 3, fig. 13.
Annularia cuspidata Lesquereux, 1884, Second Geol. Sur., Pennsylvania, Rept. Progress P, 3:725, pl. 92, figs. 7, 7a.
Annularia galioides (Lindley and Hutton), Kidston, 1891, Royal Physical Soc., Proc., 10:356.

Other references.—Jongmans (1914, 15 in part, bibliographic), Walton (1936, 229-230, pl. 31, fig. 11), Janssen (1939, 86, fig. 70).

Stratigraphic range.—Pottsville to lower Dunkard.

The leaves, 8 to 12 in a verticil, are approximately equal in length, oblanceolate, with blunt to rounded apices, and widest above the middle, tapering toward the base. Leaves at the same node with branches may be 4-5 mm. long and 0.5-1.0 mm. wide, and somewhat larger than the leaves on the lateral branches which may be as small as 1-3 mm. long and 0.3 mm. wide (Pl. 40, fig. 52). On the abaxial surface, the midvein occupies one-fourth of the width of the leaf (Chart 2).

Annularia galioides was first described by Lindley and Hutton as an *Asterophyllites.* Kidston placed it in the genus *Annularia.* Both Kidston (1911) and Jongmans (1911) considered *Ann. microphylla,* figured but not described by Sauveur, a synonym. An examination of the original material of *Ann. emersoni* Lesquereux in the U. S. National Museum showed that there is no essential difference between it and *Ann. galioides.* The single specimen of *Annularia cuspidata* Lesquereux, which bears eight verticils of leaves, is for the same reason also synonymous with *Annularia galioides.*

Potonié (1893) considered the *Ann. emersoni* of Lesquereux to be synonymous with *Ann. spicata.* Jongmans (1911) held that *Ann. spicata* is, in all probability, identical with *Ann. galioides. Annularia spicata* (Gutbier) Schimper, 1869, was refigured and redescribed by Zeiller in his Brive paper (1892). This European plant is quite distinct from the American specimens of *Ann. galioides* and in the absence of the European type specimens I hesitate to place *Ann. spicata* in the synonymy of *Ann. galioides.*

Horizon and distribution.—United States:*Pennsylvania,* Gates vein, near Pottsville—Pottsville (cited by White, 1900); Lykens Coal No. 1 at Lincoln Mine below Twin Coal in Pottsville Gap—Pottsville (cited by White, 1900; this collection lost); *Ohio,* Rushville, Perry County—Pottsville (type of *Ann. cuspidata* Lesquereux, US); St. Clairsville, Belmont County—Pottsville (type of *Ann. emersoni* Lesquereux, US); *West Virginia,* Brown's Mill, Monongalia County—Washington (WVA-G, US); *Illinois,* Mazon Creek—Allegheny (US); and CINC No. B 4106—horizon and locality unknown.

9. **Annularia latifolia** (Dawson) Kidston, 1886

Pl. 35, fig. 3; Pl. 37, fig. 21; Chart 2

Asterophyllites latifolia Dawson, 1862, Geol. Soc. London, Quart. Journ., 18:311, pl. 13, figs. 17a, b, c.

Annularia dawsoni Schimper, 1869, Traité, 1:350.

Calamites ramifer Lesquereux (in part), 1884, Second Geol. Sur. Pennsylvania, Rept. Progress P, 3:703-706, pl. 91, figs. 4, 4a.

Annularia latifolia (Dawson), Kidston, 1886, Catalogue of Paleozoic Plants, p. 226.

Annularia sphenophylloides (*non* Zenker), Stopes, 1914, Geol. Sur. Canada, Mem. 41:21, pl. 5, fig. 7.

Other references.—Dawson (1868, 538, figs. 187A, D; 1871, 28, pl. 5, figs. 50-51a; 1888, figs. A, D), Lesquereux (1880, 51), D. White (1900, 898), Matthew (1906, 125, pl. 7, figs. 2-3; 1906, 126, pl. 7, figs. 4-5), Jongmans (1913, 16-17, bibliographic), Stopes (1914, 23, pl. 6, figs. 10-12; pl. 13), Bell (1914, 100).

Stratigraphic range.—Pottsville to uppermost Allegheny.

The leaves, 7 to 12 in a verticil, occur on alternately branched axes, are openly spread apart and rarely touch or overlap the succeeding verticil (Pl. 35, fig. 3). They are oblanceolate, mucronate, widest above the middle, with a more or less rounded apex. The lateral leaves are usually somewhat longer than those parallel to the axis. The leaves usually vary from 7 to 10 mm. in length, but the variation may be from 15 to 22 mm. All are 2-3 mm. wide. The midvein is narrow and occupies approximately one-seventh of the leaf (Chart 2).

The larger striated foliate axes have internodes 13 mm. long and 1.5 mm. wide, and the nodes are slightly enlarged. Incomplete lateral branches curve upward and have approximately five internodes, ranging from 13 mm. wide at the attachment near the base of the axis to only 1 mm. wide near the tip of the axis.

Dawson based his description of his species, *Ast. latifolia,* on isolated whorls of leaves. Schimper (1869), in reviewing Dawson's data, recognized that it belonged to the genus *Annularia* and renamed the species, *Ann. dawsoni.*

Lesquereux (1880) concurred with Schimper that the species belonged to *Annularia* and cited it as *Ann. dawsoni.* In 1884, he described *Calamites ramifer* (?) based on large axes, 6-12 cm. in diameter, which bore branches with attached whorls of leaves. The description and figures of the leaves agree with the description of the leaves of *Ann. latifolia.*

Kidston (1886) upheld the generic designation, *Annularia,* and re-established Dawson's original specific name, *Ann. latifolia,* and cited *Ann. dawsoni* as a synonym.

David White (1900) agreed that the leaves of *Calamites ramifer,* described by Lesquereux in 1884, belonged to the species, *Ann. latifolia.*

Matthew (1906) separated a smaller form, as *Ann. latifolia* var. *minor;* but Bell (1944) indicated clearly that the normal size variation of *Ann. latifolia* includes all of the features of Matthew's variety.

The branches of *Ann. latifolia* which bear smaller leaves resemble *Ann. sphenophylloides* in habit and branching; however the inequality of leaf length in a verticil of *Ann. latifolia* separates it from *Ann. sphenophylloides.*

Annularia latifolia (Pl. 35, fig. 3) with 7 to 12 oblanceolate leaves in each verticil with their maximum width approximately mid-length of the leaf, can be distinguished from the somewhat similar *Ann. stellata* (Pl. 35, fig. 1), because 16 to 32 lanceolate leaves are widest nearer the apex.

Horizon and distribution.—Canada: *Northern Nova Scotia,* Cumberland group—upper Pottsville (cited by Bell, 1944); *New Brunswick,* Lancaster, "Fern Ledges"—Pottsville (cited by Bell, 1944); *St. John,* Cumberland group—Pottsville (cited by Bell, 1944). United States: *Pennsylvania,* Pottsville Gap, below Twin Coal, Upper Lykens—Pottsville (cited by White, 1900); Campbell's Ledge, Pittston—Pottsville (cited by White, 1900); *Virginia,* Fayette formation—Allegheny (cited by White, 1900); *Ohio,* Kimberly, Athens County — upper Freeport — upper Allegheny (CINC-T).

10. **Annularia mucronata** Schenk, 1883 Pl. 35, fig. 5; Pl. 36, figs. 10, 11, 13, 14, 16-18; Pl. 41, fig. 57; Pl. 42, figs. 59, 61; Chart 2

Annularia mucronata Schenk, 1883, in Richthofen, F. P. W., China, Paleontologischer Theil 4:226, pl. 30, fig. 10, text figure 10.
Annularia sphenophylloides var. *intermedia* Lesquereux, 1884, Second Geol. Sur. Pennsylvania, Rept. Progress P, 3:724.
Annularia stellata Zeiller (in part), 1888, Études des Gîtes minéraux de la France, pp. 399-403.
Annularia stellata forma *mucronata* Bell (in part), 1938, Geol. Sur. Canada, Mem. 215:85, pl. 89; pl. 91, fig. 1.

Other references.—Potonié (1893, 161, 164), White (1899, 159-162, pl. 24, fig. 3b), Jongmans (1911, 239, 248) and Halle (1927, 32-34, pl. 7, figs. 1-8, ?fig. 9).

Stratigraphic range.—Throughout the Allegheny to mid-Dunkard.

The spatulate leaves, 10 to 24 in a verticil, are 4-25 mm. long and 1.5-3.5 mm. wide and widest near the apex. The lateral leaves, those lying more or less at right angles to the axis (Pl. 39, fig. 5; Pl. 41, fig. 57) are almost twice as long as those lying more or less parallel to the axis. This arrangement gives the verticil an elliptical shape with the greatest diameter at right angles to the axis. The margins of the leaves are straight and strongly divergent. The leaf increases in width from the sheath to the broad, rounded and strongly mucronate tip (Chart 2; Pl. 35, fig. 4). Some of the leaves may appear to be retuse or obcordate at the tip due to a partial burial in the matrix. The abaxial leaf surface and the sheath bear simple, sharply pointed hairs about 1 mm. long (Pl. 42, fig. 59). The conspicuous sheath is 1.5-2.0 mm. wide. The midvein is strong, 0.35 mm. wide and flares out at the tip.

The leaves are borne on hairy (Pl. 42, fig. 61), obscurely striated, alternately branched axes. The nodes are prominent and the internodes are 10-25 mm. long and 0.5-3.0 mm. wide.

Transfer preparations show that the abaxial epidermis (Pl. 36, fig. 14) is essentially like that described for *Ann. stellata* (Pl. 36, fig. 19) except for the presence of many simple, long-tapering, acutely pointed hairs (Pl. 42, figs. 59, 61) on *Ann. mucronata.* The hairs, although more numerous near the midvein and on the sheath, are scattered over the whole of the lower lamina (Pl. 42, fig. 61). They are more or less straight to falcate, averaging 1 mm.

in length, although they may be as long as 1.3 mm. No septa are visible, and the hairs appear to be extensions of single epidermal cells (Pl. 36, figs. 11, 13).

In some transfer preparations the midvein area below the epidermis includes about four rows of annulate (perhaps spiral) tracheids (Pl. 36, fig. 18), 8.75-12.5 mu wide, bordered on the right and left by uniformly thickened cells, some of which are barrel-shaped, averaging 81 mu long and 38 mu wide, others rectangular, about 118 mu long and 31 mu wide. Toward the base of the leaf the midvein area includes several rows of scalariform tracheids (Pl. 36, figs. 10, 16), each 35-40 mu wide, with barrel-shaped and rectangular cells to the right and left as shown in Figure 18 (and probably encircling it).

The variation in the length of the leaves is conspicuous not only within the single verticil but also between the verticils which increase in size toward the base of the axis. For example, in one small axis (Pl. 41, fig. 57) consisting of eight verticils, the leaves of the apical whorl are 4-7 mm. long and 1.5 mm. wide, leaves of adjacent whorls are proportionately larger until those of the fifth whorl are 7-11 mm. long and 2 mm. wide. The internodes are 11 mm., 12 mm., and 13 mm. long, and 0.5-1 mm. wide. Larger specimens bear lateral leaves to 24 mm. long and 3.5 mm. wide. The number of leaves in a whorl increases from 10 in the small apical verticils to 24 in the larger verticils.

Ann. mucronata was first described by Schenk (1883) from plants collected in China. Lesquereux (1884) described *Ann. sphenophylloides* var. *intermedia* from Lawrence, Kansas, (now in the Lacoe Coll. in the National Museum) and it is not different from *Ann. mucronata* Schenk. Bell (1938) described *Ann. stellata* forma *mucronata* from Canada, and this plant agrees also with *Ann. mucronata.* Other authors, Zeiller (1888), Potonié (1893), and Jongmans (1911), although not unconditionally, include this species in *Ann. stellata.*

The leaves of *Ann. mucronata* are intermediate in size between those of *Ann. sphenophylloides* and *Ann. stellata.* The maximum leaf length in *Ann. mucronata* is 25 mm. while that in *Ann. spenophylloides* is 12 mm. and *Ann. stellata* is 50 mm.

The form of the leaves of *Ann. mucronata* is unlike that of *Ann. stellata*. They are widest near the apex, while those of *Ann. stellata* are widest near the middle. *Ann. mucronata* has a maximum of 24 leaves in a verticil and *Ann. stellata* may have up to 36.

The verticils of *Ann. mucronata* differ from those of *Ann. sphenophylloides* in that the former are progressively larger from the apex to the base of the axis, while those of *Ann. sphenophylloides* are approximately uniform in size throughout (compare fig. 57 with 55, Pl. 41). The leaves of a single whorl of *Ann. mucronata* are more widely spaced and the margins seldom touch one another, while in *Ann. sphenophylloides* the margins of adjacent leaves are typically approximate and parallel.

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, from the Tracey seam to the roof shales of the lower Point Aconi seam, *Linopteris* zone—Allegheny (cited by Bell, 1938). United States: *Missouri,* Pitcher's Coal Bank and near Clinton, Henry County—Allegheny (US); *Illinois,* Mazon Creek—Allegheny (US); *Pennsylvania,* Jollytown—Dunkard (US); *West Virginia,* Wiseville, Monongalia Co., "Jollytown" Coal—Dunkard (US); Brown's Mill, Washington shale—Dunkard (US); near Cassville, Cassville shale—Dunkard (US); west of Price, shale near Washington Coal—Dunkard (WVA-G); northwest of Price, Washington shale below Washington Coal—Dunkard (WVA-G); Worley, Washington shale below Washington Coal—Dunkard (WVA-G); *Ohio,* Athens Co., Lodi township, Pittsburgh 8A Coal—Monogahela (WVA-G, OU, CINC); Kimberly, upper Freeport—uppermost Allegheny (CINC-T); *Kansas,* Fairgrounds in Lawrence—upper Allegheny (US); *Rhode Island,* locality unknown—Allegheny (US). Also known from Europe and China.

11. **Annularia radiata** (Brongniart) Sternberg, 1825 Pl. 41, fig. 56; Chart 2

Asterophyllites radiata Brongniart, 1822, Memoirs du Museum d'histoire Naturelle, Paris, 8:35, 89, pl. 2, figs. 7a-7b.

Annularia radiata (Brongniart), Sternberg, 1825, Flora der Vorwelt, I, 4, Tentamen, p. xxxl.

Annularia ramosa (Weiss), D. White, 1893, United States Geol. Sur., Bull. 98:17.

Other references.—White (1899, 158), Jongmans (1914, 28-32, in part, bibliographic; 1923, 747, 748, in part, bibliographic), Noé

(1925, 13, pl. 4, fig. 2), Jongmans (1935, 405, 409, pl. 33, figs. 104-106; pl. 26, fig. 71; pl. 25, fig. 68), Walton (1936, 232, pl. 31, figs. 16, 17), Bell (1938, 85, pl. 88, fig. 2), Janssen (1939, 68), Arnold (1949, 183-184, pl. 17, fig. 3).

Stratigraphic range.—Pottsville to Conemaugh.

The linear-lanceolate leaves 8 to 20 in a verticil, are commonly 14-15 mm. long and about 1.25 mm. wide but may vary from 7-30 mm. long and from 0.5-2 mm. wide. They are more or less uniform in width except for the tapering ends. The apex is acutely pointed. The leaves, radiating from the node, are lax and of equal length. They are usually flattened in the plane of the axis, often overlap those of the succeeding whorl. The midvein occupies one-fourth to one-fifth the width of the leaf.

The ultimate branches are lax, flexuous, alternate, and form both oblique and nearly right angles with the larger branches. The axes of the largest branches are striated, with the internodes 15-30 mm. long and 0.5-3 mm. wide. The ultimate branches are 7-15 mm. long and 0.5-2 mm. wide.

Annularia radiata is distinctive because of its lax habit (Pl. 41, fig. 56). The leaves are often bent in the plane of the whorl, usually near the middle. This disarray of the leaves gives each whorl a pattern quite different from the symmetrical patterns displayed by *Ann. sphenophylloides* (Pl. 41, fig. 55) or *Ann. galioides* (Pl. 40, fig. 52).

Weiss (1881) and Stur (1887) independently discovered that certain forms of *Ann. radiata* were attached to *Calamites ramosus*. Both gave this foliage the name *Ann. ramosa* and initiated the difficult problem of determining whether all specimens described as *Ann. radiata* belong to this species of *Calamites* or whether there are two similar species; namely, *Ann. radiata* based on the type described by Brongniart, which has never been found attached, and the *Ann. ramosa* Weiss based on the leaves attached to *Calamites ramosus*. Another problem is that if two species exist, do both occur in American collections? D. White, 1893, discussed this problem at length and expressed the opinion that all of the American specimens of *Ann. radiata* are essentially similar to the European material which is attached to *Calamites ramosus* and is thus recognized as *Ann. ramosa.* According to White the material of Weiss and Stur differs from that of *Ann. radiata* of Brongniart. He quoted Weiss and Stur to the effect that Brongniart's *Ann. radiata* had a verticil diameter of 3.5 cm., while the verticils attached to *Calamites ramosus* were about 2.5 cm. in diameter. He also suggested that the width-length ratio of the leaves of *Ann. radiata* Brongniart is less than in that of leaves of *Ann. ramosa.*

A review of many specimens in the U.S. National Museum, in part identified as *Ann. ramosa* and in part as *Ann. radiata* by both Lesquereux and by White, indicates that they all belong to one species. They are like *Ann. radiata* as described by Brongniart. The specimens examined from Ohio, ranging in age from the lower to the upper Allegheny, also belong to the species *Ann. radiata.* All of these agree in being isolated verticils or branchlets unattached to any calamitean stem and all agree in having verticils of the larger size, 3.5-5.5 cm. in diameter. The other characteristics also closely approximate those of Brongniart's *Ann. radiata.* There is no basis for the introduction of the species *Ann. ramosa* for any American material described thus far. Whether the attached European foliage is sufficiently distinct from *Ann. radiata* to require separate consideration is doubtful.

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, Bouthillier seam—Conemaugh (cited by Bell, 1938). United States: *Missouri,* Deepwater, McClelland's shaft near Bellville, and Lawrence Co. near Aurora—Pottsville (US); *Michigan,* above Grand Ledge Coal—upper Pottsville (cited by Arnold, 1949); *Illinois,* Mazon Creek and Will Co., Wilmington strip mine, Carbondale formation—Allegheny (US, CINC, and cited by Noé, 1925); *Ohio,* Athens Co., Kimberly—uppermost Allegheny (CINC-T); Carbondale—middle Allegheny (CINC-T); Vinton Co., McArthur —lower Allegheny (CINC-T); *Pennsylvania,* Lorberry Gap, Yoder's drift, Lykens No. 4—Pottsville (cited by White, 1900); *Tennessee,* near Sharon, horizon unknown (cited by Lesquereux, 1880).

12. **Annularia sphenophylloides** (Zenker) Gutbier, 1837

Pl. 37, fig. 24; Chart 2

Galium sphenophylloides Zenker, 1833, Neues Jahrbuch, pp. 398-400, pl. 5, figs. 6-9.

Annularia sphenophylloides (Zenker), Gutbier, 1837, Isis von Oken, p. 436
Annularia brevifolia Newberry, 1853, Ann. Science, Cleveland, I:97.

Other references.—Jongmans (1914, 35-39, in part, bibliographic; 1923, 749-750 bibliographic), Walton (1936, 228-229), Bell (1938, 84, pl. 85, fig. 3; pl. 87, fig. 1), Janssen (1939, 86, fig. 69), Bell (1940, 129).

Stratigraphic range.—Pottsville to Dunkard.

The spatulate leaves number 10-20 in a verticil which on smaller branches may touch or overlap the next higher verticil (Pl. 35, fig. 6; Pl. 41, fig. 55). The whorls of leaves also occur at the nodes of axes from which one or two branches arise (Pl. 41, fig. 55). The verticils are spread apart with the margins of adjacent leaves nearly parallel and approximate (Pl. 35, fig. 6). Within a verticil the leaves directed away from the axis may be slightly longer than those which are more or less parallel to it. The sheath is narrow and inconspicuous and is but one-third to one-half a millimeter wide.

The margins of the leaves are straight (Chart 2), the leaf increasing in width to the broad, rounded, mucronate tip. The ends of some of the leaves appear retuse or obcordate at the tip due to a partial covering by the matrix. Leaves vary from 3-12 mm. long and from 0.5-1.5 mm. wide in different verticils. The midvein, in transfer preparations, is strong and flares out at the tip and occupies one-fifth the width of the leaf.

The epidermis, both adaxial and abaxial, is like that described for *Annularia stellata.*

This species bears a general resemblance to *Ann. stellata* but may be distinguished from it by the form of the leaf. The latter is widest at or near the middle, while *Ann. sphenophylloides* is widest at the tip. The lateral margins of the leaf of *Ann. sphenophylloides* are straight while those of *Ann. stellata* are convex. The verticil of *Ann. sphenophylloides* is essentially symmetrical even though there may be some variation of individual leaf length, while that of *Ann. stellata* is conspicuously asymmetrical. Also, the number of leaves per verticil in *Ann. stellata* is usually greater.

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, about 200 feet below the Tracey seam to the top of the Morien series at Point Aconi—throughout Allegheny (cited by Bell, 1938); Pictou Coalfield, Thorburn member of the Stellarton series—Allegheny; Pictou series—Allegheny (both cited by Bell, 1940); *New Brunswick,* St. John, Cumberland group—Pottsville (cited by Bell, 1944). United States: *Missouri,* Belleville, Cartersville, Deepwater, Gilkerson's Ford, and Owens Coalbank—Pottsville (US); *Pennsylvania,* Cannelton and Pottsville—Pottsville (US); Fayette Co., German township, Pittsburgh Coal—Monongahela (WVA-C); *Illinois,* Braidwood—Allegheny (cited by Noé, 1925), Mazon Creek—Allegheny (US, CINC, and cited by Noé, 1925); *Oklahoma,* McAlester Coal—Allegheny (US); *Kansas,* Lawrence, Lawrence shales—Allegheny (US); *Ohio,* Vinton Co., Elk township, McArthur—lower Allegheny (CINC-T), Athens Co., Kimberly—uppermost Allegheny (CINC-T), Athens Co., Lodi township, Shade Creek, Pittsburgh 8A—Monongahela (WVA-C, OU, CINC, CINC-T), Athens Co., near Nelsonville, above lower Freeport Coal—Allegheny; Meigs Co., Pittsburgh 8A Coal—Monongahela (WVA-S), Munroe Co., Center township, above Jollytown "A"—Dunkard (WVA-S); *West Virginia,* Monongalia Co., Worley—Dunkard (WVA-G), near Kempton, mostly in Granite Co., Pittsburgh Coal—Monongahela (WVA-G), Cassville—Dunkard (WVA-G); *Indiana,* Friar Tuck pit, Duggar formation—upper Allegheny (CINC); *Rhode Island,* neither locality or horizon known (US).

13. **Annularia stellata** (Schlotheim) Wood, 1860 Pl. 35, fig. 1; Pl. 36, figs. 8-9; Pl. 41, fig. 58; Pl. 43, figs. 62, 64; Pl. 49, fig. 87; Chart 2

Casuarinites stellatus Schlotheim, 1820, Die Petrefactenkunde, Gotham, p. 397.

Annularia spp. Hitchcock, 1841, Geol. Massachusetts, Final Report, II:542, 754, fig. 226; pl. 22, fig. 2; pl. 23, fig. 1.

Annularia stellata (Schlotheim), Wood, 1860, Acad. Nat. Sci. Philadelphia, Proc., 12:236.

Annularia longifolia Lesquereux, 1866, Geol. Sur. Illinois, Report, II, Paleontology, p. 444.

Annularia inflata Lesquereux, 1870, Geol. Sur. Illinois, IV, 2:423, pl. 20, figs. 1-3.

Carpannularia americana Elias, in part, 1931, Univ. Kansas Sci. Bull., 20(5):115-159, pl. 12, pl. 13; pl. 14, figs. 1a-c, 3a (leaves only); pl. 15, fig. 1 (leaves only), fig. 2.

Annularia stellata forma *mucronata* Bell, in part, 1938, Geol. Sur. Canada, Mem. 215:85, pl. 90, figs. 1-2.

Annularia stellata forma *longifolia* Bell, 1944, Geol. Sur. Canada, Mem. 238:102, pl. 70, fig. 5.

Other references.—Jongmans (1914, 41-46, bibliographic; 1923, 751-752, bibliographic), Noé (1925, 13, pl. 3), Walton (1936, 233-235, pl. 32, figs. 24-29), Bell (1938, 85, in part, pl. 90, figs. 1-2), Janssen (1939, 84, fig. 67; 1940, 9-12, pl. 1, fig. 1), Bell (1944, 102, pl. 70, fig. 5), Arnold (1949, 184, pl. 17, fig. 1).

Stratigraphic range.—Pottsville to Dunkard.

The leaves, 13 to 32 in a verticil, are oblanceolate and mucronate. They are 1.4-7.5 cm. long, most commonly 2.5-3 cm. long, and 0.5-3 mm. wide, with the greatest width at or slightly above the middle of the leaves. The midvein is 0.3-0.5 mm. wide and occupies one-fifth to one-third of the width of the leaf. The sheath is up to 1.5-2 mm. wide.

The leaves are borne on obscurely striated distichous and opposite branched axes whose nodes are only slightly enlarged. The internodes are 1.2-3.5 cm. long and 2-5 mm. wide. On smaller axes, the whorls overlap.

The leaves of a verticil are rarely of equal length (Pl. 35, fig. 1; Pl. 41, fig. 58). Usually the lateral leaves, those lying more or less at right angles to the axis, are longer than those lying more or less parallel to the axis and the verticil is elliptical in outline with its greatest diameter at right angles to the axis. On occasion, the lateral leaves may be but slightly longer than the others so that the verticil appears circular. Again the lower leaves may be shorter than the upper leaves of the verticil, although both are shorter than the lateral leaves, so that the verticil appears acentric. All of these variations may occur on the same branch.

Transfer preparations show that the adaxial epidermis is composed of thin-walled cells elongated parallel to the midvein and devoid of stomata. On the abaxial epidermis (Pl. 36, fig. 9; Pl. 43, fig. 62) the area above the midvein is composed of 5-6 rows of thin-walled cells elongated parallel to the midvein, with their end walls more or less at right angles. There are no stomata in this area. On this surface the epidermis of the lamina from the midvein to the leaf margin is composed of thin-walled cells with walls straight or essentially so. In contrast to the cells over the midvein, these are usually elongated in the direction of the leaf margin at an oblique angle to the midvein (Pl. 36, fig. 9; Pl. 43, fig. 62). Stomata are abundant in this area and are not confined to a groove or narrow band as many have previously assumed. Each stoma is surrounded by two guard cells and two accessory cells. The guard cells are inconspicuous, small, sunken, and often not readily discernible. The accessory cells are conspicuously kidney-shaped and average about 60 mu long and 20 mu wide.

The outline of the verticils of *Ann. stellata* shows more variation than that of other species of the genus. This is largely due to the varying lengths of the leaves in a verticil, to the variation in size and to some extent to the form of the leaves, to the size of the branch which bears them, and to variations in preservation which have been erroneously interpreted in terms of "absence" of a midvein or to an atypical appearance.

Annularia longifolia Brongniart has been placed in synonymy with *Ann. stellata.* A study of the specimens of *Ann. longifolia* Lesquereux (1866) from Cannelton, Pennsylvania, in the Lacoe Collection in Washington, shows that this species belongs to *Ann. stellata.*

Lesquereux (1870) proposed the species, *Ann. inflata,* for a specimen from Mazon Creek, Illinois, in which he assumed that the leaves had a rounded or subcylindrical form, and in which the leaf margins incurved toward the adaxial surface, and the midveins were obscure. Because of this and a variation in preservation, the plants were erroneously considered to be different from the typical *Ann. stellata.* A study of the specimens of *Ann. inflata* in the Lacoe Collection at the U. S. National Museum demonstrates that this species belongs to *Ann. stellata.*

One of the specimens on which Elias (1931) based his description of *Carpannularia americana,* loaned for this study by the California Academy of Sciences, shows that the leaves of this plant agree with *Ann. stellata.* The photomicrographs of Elias (1931, pl. 15, fig. 2 at 1 o'clock) shows the same cellular arrangement on the adaxial epidermis as that seen in figure 9, Plate 36, and figure 62, Plate 43. Elias observed the parallel arrangement of the cells over the midvein and the general orientation of the cells in the remainder of the lamina; that is, at angles of less than

90° with the midvein. He believed that "hairs" covered the entire surface of the leaf and that the "hairy"covering perhaps reflected the arrangement of the epidermal cells below. Many of the cells in chainlike series have dark-colored contents. These are the ones that Elias interpreted as hairs with blunt ends. I have not been able to observe a hair, with certainty, on the lamina, the sheath, or the axis.

One of the specimens from Kimberly, Ohio, also shows a globular structure similar to those found on the plant that Elias described from Missouri.

Bell (1938) described *Ann. stellata* forma *mucronata* based on leaves with mucronate apices. Transfer preparations of specimens of *Ann. stellata,* collected from Pottsville through Monongahela horizons, have been made. Whenever the preservation of the apex is complete, it is mucronate. I believe that Bell had material of both *Ann. mucronata* and *Ann. stellata* under this forma, and I have considered those specimens which have spatulate leaves with broad rounded apices and a mucronate tip to belong to *Ann. mucronata.* The rest remain in *Ann. stellata.*

Bell (1944) described and figured a specimen of *Ann. stellata* which, although conforming to the general description for this species in numbers of leaves in a whorl and general outline, possesses leaves which exceed the usual length. They are 7.5 cm. long and 1.5-2 mm. wide. He suggested that since this form is from the upper part of the Cumberland group only, it could be used as a horizon marker and should be designated as *Ann. stellata* forma *longifolia.*

Walton (1936), in discussing the factors which influence the external form of plants, especially those which affect the appearance of *Annularia* leaves, demonstrates how various local factors during fossilization and the condition of the leaf before fossilization help to explain the many difficulties involved in identification.

Stur (1887) proposed dividing *Ann. stellata* into three species based on the following leaf characteristics, all of which can be explained as variations of the leaf before and during fossilization: *Ann. stellata* with thickened leaf margins; *Ann. westphalica* with crowded lateral leaves and none covering the axis; *Ann. geinitzii* with the abaxial surface chagrined or "hairy" in appearance.

In respect to the hairy appearance, the transfer methods (Walton, 1936 and Abbott, 1950, 1952) show that a chagrined or "hairy" leaf surface is merely a condition of the epidermis. Many leaves are heavily carbonized and the epidermal pattern is partly obscure. There, the so-called hairs and their arrangement are nothing more than the epidermal pattern. To date, true hairs, which Walton (1936) shows on *Ann. fimbriata,* plate 32, figures 20-21, or those of *Ann. mucronata* at figure 69, have not been observed on *Ann. stellata.*

Horizon and distribution.—Canada: *New Brunswick,* St. John, Lancaster, "Fern Ledges," Cumberland group—upper Pottsville (cited by Bell, 1944) and *Nova Scotia,* Sydney Coalfield, Pictou-Stellarton series—middle Allegheny (cited by Bell, 1938). United States: *Illinois,* Mazon Creek—Allegheny (CINC, US); Wilmington strip mine, Will Co., Carbondale formation—Allegheny (WVA-G); Braidwood—Allegheny (cited by Noé, 1925); *Missouri,* Pitcher's Coal Bank, Hobb's Coal Bank, Owens Coalbank, Deepwater, Gilkerson's Ford—all Pottsville (all at US), Henry Co., Windsor, above Crowberg Coal—Allegheny (WVA-C); *Pennsylvania,* Cannelton—Allegheny (US), Mahoney City, Plymouth, and Shainokin—horizons unknown (US); *Oklahoma,* McAlester Coal—Allegheny (US); *Indiana,* locality unknown, Coal Measures —Allegheny (US); *Michigan,* between cycles "B" and "E"—middle Pottsville (cited by Arnold, 1949); *Ohio,* McArthur, Vinton Co.—lower Allegheny (CINC-T), Kimberly, Athens Co.—uppermost Allegheny (CINC-T), Lodi township, Pittsburgh 8A—Conemaugh (CINC, WVA-C, CINC-T), near Carbondale, Clarion Coal—lower Allegheny (CINC), near New Straightsville, Hocking Co., middle Kittanning—middle Allegheny (WVA-S), Bares Run, Munroe Co., rider "B", Jollytown "A"—Dunkard (WVA-S), Center township, above Jollytown "A"—Dunkard (WVA-S), Galia Co., Glenwood quadrangle, Pittsburgh Coal—Monongahela (WVA-G, WVA-S); *West Virginia,* West Union, Doddridge Co., Waynesburg "A"—lower Dunkard (WVA-S), Lincoln District, Marion Co., Cassville shale—Dunkard (WVA-S), near Price, Monongalia Co., Washington shale below Washington Coal—Dunkard (WVA-C), near Worley, shale near Washington Coal—Dunkard (WVA-C), Wetzel Fish Creek horizon—Dunkard (WVA-C), near Kempton, mostly in Granite Co., Pittsburgh Coal—Monongahela (WVA-S); *Kansas,* Thayer, Neosho Co.—horizon unknown (US).

14. **Annularia vernensis** (Arnold) Abbott, comb. nov.
Pl. 37, fig. 24; Chart 2

Asterophyllites vernensis Arnold, 1949, Univ. Michigan Museum Paleontology, Cont., 7(9):182-183, pl. 16, figs. 6-9.

Other references.—None.

Stratigraphic range.—Lower Pottsville.

The leaves, averaging 12 in a verticil, are 5 mm. long and 1 mm. wide. Each leaf is longer than the internode. They are conspicuously lanceolate (Pl. 37, fig. 24), more or less uniform in width, taper basally, and to the acute apex. They are of equal length, radiating from the node, spreading, and are straight or slightly curved. The midrib is 0.3 mm. wide and longitudinally striated. The stem is 1 mm. wide with internodes 3-4 mm. long (Pl. 37, fig. 24).

This description is based on a specimen of *Asterophyllites vernensis* kindly supplied by Dr. C. A. Arnold. The specimen is a branch tip consisting of parts of approximately 15 verticils of leaves each of which is longer than the internode. Arnold interpreted the arrangement of the leaves in each verticil as forming an open cup and his selection of the generic designation *Asterophyllites* is based on this interpretation.

It appears to me that the leaves radiate from the node (Pl. 37, fig. 24) in a single plane characteristic of the habit of *Annularia,* and that they possess a width-length ratio (Chart 2) and form more consistent with that of *Annularia* than with *Asterophyllites.* I agree with Arnold in the belief that this specimen represents a species not heretofore recognized, although in size and general appearance it most closely resembles *Ann. galioides.* It differs from *Ann. galioides,* in that it has a lanceolate leaf while *Ann. galioides* has a spatulate leaf. The leaves of *Ann. vernensis* more or less cup the axis, while those of *Ann. galioides* radiate from the node.

Horizon and distribution.—United States: *Michigan,* Grand Ledge, below Cycle "A"—lower Pottsville (CINC-T, and cited by Arnold, 1949). Known only from the United States.

III. **Sphenophyllum** Brongniart, 1822

Sphenophyllum Brongniart, 1822, Memoirs du Museum d'histoire Naturelle, Paris, 8:209, 234.
Rotularia Sternberg, 1823, Flora der Vorwelt, 1, 2:33.
Trizygia Forbes Royale, 1839, Illustrations of the Botany of the Himalayan Mountains and the Flora of Cashmere, I, p. xxix.

The leaves occur in superposed verticils of six, eight or nine at a node and all stand out at the same angle to the axis. The verticil is radially symmetrical and in compressions all of the leaves usually lie in a plane parallel to the axis. The leaves are cuneate to broadly ovate with lateral margins convex, straight or concave. The distal margins may be straight to arching, undivided, set with pointed or blunt teeth, to laciniate or fringed, to deeply lobed or even filamentous. One vein enters the base of the leaf and undergoes one to several dichotomies before the resulting veinlets terminate at the distal margin. The leaves are dorsi-ventral; the cells of both the adaxial and abaxial epidermis are relatively thin-walled, elongated in the direction of the long axis of the leaf, with undulate lateral walls somewhat thicker than the more or less inclined undulate end walls. Stomata occur on the abaxial leaf surface where two kidney-shaped, sunken guard cells are surrounded by approximately three to five irregular accessory cells. In two species, minute hairs, some to 135 mu long, others to 1 mm., occur on the margins of the leaves.

KEY TO THE SPECIES

A. Leaves in a verticil of equal length
 a. Leaves with width-length ratio 1:2
  b. Lateral margins slightly to strongly concave
   c. Distal margin without a central cleft
    d. Leaf symmetric, 8 mm. wide, 10-20 mm. long, widest near distal margin .... 27. *Sph. tenue*
    dd. Leaf asymmetric, 8-10 mm. wide, 10-15 mm. long, widest near the middle .... 26. *Sph. obovatum*

cc. Distal margin with a median cleft
  e. Cleft less than one-third the length of the leaf, teeth blunt-obtuse, leaf 4-6 mm. wide, 8-10 mm. long .... 19. *Sph. emarginatum*
  ee. Cleft more than one-half the length of the leaf, lobes widely spreading, leaf 3 mm. wide, 5 mm. long........ 31. *Sph. trichomatosum*
bb. Lateral margins straight to convex
  f. Distal margins straight to convex
    g. Lobes 2 to 4
      h. Teeth of distal margin sharply pointed
        i. Leaves 2-5 mm. wide, 5-10 mm. long ......18. *Sph. cuneifolium*
        ii. Leaves 2.5-8 mm. wide, 12.5-20 mm. long ......24. *Sph. majus*
      hh. Teeth of distal margin blunt, leaves 4-6 mm. wide, 8-10 mm. long ....19. *Sph. emarginatum*
    gg. Lobes 7-9, long, narrow, extending to the middle of the leaf; leaf 9-12 mm. wide, 15-18 mm. long ....17. *Sph. cornutum*
  ff. Distal margins strongly rounded to ovate
    j. Distal margin entire to slightly erose; leaf 4-8 mm. wide, 15-50 mm. long ....21. *Sph. gilmorei*
    jj. Distal margin with numerous short, acute teeth to fimbriate; leaf 7-25 mm. wide, 15-50 mm. long ....30. *Sph. thoni*
aa. Leaves with width-length ratio 1:3 or more
  k. Distal margin of leaf with 6 or more short, sharp teeth; lateral margins convex; leaves 1-2 mm. wide, 10-11 mm. long ....29. *Sph. tenuifolium*
  kk. Distal margin of leaf lobed
    l. 2-lobed
      m. Median cleft less than one-half the length of the leaf, lobes short, blunt to sharp, leaf 1-1.75 mm. wide, 3.4 mm. long ....22. *Sph. lescurianum*
      mm. Median cleft extending halfway or more to base of leaf
        n. Leaf cleft to middle, teeth broad, sharp pointed; leaf 1.5-3 mm. wide, 5-10 mm. long ....15. *Sph. angustifolium*
        nn. Leaf cleft two-thirds or more to base of leaf
          o. Lobes broad, blunt, with a varying number of sharp teeth; leaves average 10 mm. wide and 30 mm. long........ 23. *Sph. longifolium*

oo. 2 elongate-tapering, acute lobes; leaf 1-1.5 mm. wide, 2.5-4 mm. long ....20. *Sph. fasciculatum*

ll. More than 2-lobed

p. Leaf cleft to one-fourth the length, lobes mostly 3-toothed ....15. *Sph. angustifolium*

pp. Leaf cleft more than one-fourth the length

q. Lobes of unequal length

r. Lobes long-tapering to a point, lobes 0.25-0.33 mm. wide ....28. *Sph. tenerrimum*

rr. Lobes broad, blunt, each with a shallow cleft, lobes 1 mm. wide ....31. *Sph. trichomatosum*

qq. Lobes of equal length

s. Center cleft almost to base of leaf

t. Outermost clefts to lower one-third of leaf, lobes widely spreading, pointed, 0.25-0.33 mm. wide, leaf up to 9 mm. long ....18. *Sph. cuneifolium* (*Sph. myriophyllum*)

tt. Outer clefts to the upper one-third of leaf, lobes 1 mm. wide, blunt; leaf to 4 mm. long ....16. *Sph. arkansanum*

ss. Center clefts one-third to one-half the length of the leaf; lobes 2.5 mm. wide, tapering, with sharp-pointed teeth; leaf 10-11 mm. long ....18. *Sph. cuneifolium* (*Sph. saxifragaefolium*)

AA. Leaves in a verticil of unequal length

u. Leaves of verticil of 2 lengths, deflexed pair shorter than other four; distal margin of leaf more or less straight, 2-4 lobed with 2-8 sharp teeth; leaf 4-5 mm. wide, 3-5-18 mm. long ....25. *Sph. oblongifolium*

uu. Leaves of verticil of 3 lengths, deflexed pair shortest; distal margin arching to rounded with short, blunt teeth; leaf 3-5 mm. wide, 5-20 mm. long ....32. *Sph. verticillatum*

15. **Sphenophyllum angustifolium** (Germar) Geoppert, 1848
Pl. 38, figs. 35, 40-41; Pl. 44, fig 65, Pl. 49, fig. 90; Chart 3

Sphenophyllites angustifolius Germar, 1845, Die Versteinerungen des Steinkohlengebirges von Wettin und Löbejün *in* Saalkreise, Halle, 2-3:18, pl. 7, figs. 4-7, ?8.

Sphenophyllum angustifolium (Germar), Geoppert, 1848, *in* Bronn, Index paleontologicus, Stuttgart, 1:1166.

Sphenophyllum trifoliatum Lesquereux, 1858, *in* Rogers, Geol. Sur. Pennsvlvania, 2:853, pl. 1, fig. 7.

Sphenophyllum bifurcatum Lesquereux, 1878, 1880, Second Geol. Sur. Pennsylvania, Rept. Progress P, Harrisburg, 1:55-56, Atlas, pl. 2, figs. 10-10a.

Other references.—Fontaine and White (1880, 37, pl. 1, figs. 7, 7a), Jongmans (1936, 1086-1088 bibliographic).

Stratigraphic range.—Allegheny to Dunkard.

The leaves, six in a verticil, are elongate-cuneate to bifid, 3-14 mm. long and 1.5-3 mm. wide at the distal margin. The sides are straight to more or less convex and the distal margin is essentially straight with 2-5 tapering, sharp-pointed teeth; when present, the central cleft may be 1.5-2 mm. deep with minor clefts on either side, 0.7-1.5 mm. deep. The leaves of the main axis and at the bases of lower axes are for the most part undivided, while in their progression toward the branch apex, they become smaller and more deeply cleft. One vein enters the base of the leaf and after several bifurcations each lobe or tooth at the distal margin contains a veinlet. (Chart 3).

The larger axes are 4 mm. wide with internodes 3.5-3.7 cm. long; lateral branches, perhaps secondary, are 1-2.5 mm. wide with internodes 3-10 mm. long; ultimate or third order branches are 1 mm. wide with internodes 5-7 mm. long. The internodes of all three orders of branches are longitudinally striated between the slightly enlarged nodes.

The abaxial epidermis (Pl. 38, fig. 35) is composed of elongated, thin-walled cells, averaging 35 mu long and 8 mu wide. The undulate lateral walls are elongated in the direction of the long axis of the leaf. End walls are usually inclined but some may be more or less straight. No stomata were observed. Hairs which occur along the sides of some of the leaves (Pl. 38, figs. 40, 41; Pl. 44, fig. 65) are simple, to 135 mu long and appear to be an extension of an ordinary epidermal cell.

The more deeply dissected leaves of *Sph. angustifolium* are the ones usually figured, since these are more commonly seen than are the toothed or entire leaves. On smaller axes, the leaves cup around the axis and the entire whorl is seldom flattened in the plane of the axis.

In most heterophyllous species of *Sphenophyllum* the more deeply dissected leaves occur toward the base of the axis (cf. *Sph. cuneifolium*) and the more nearly entire leaves toward the apex. The reverse of this situation occurs in *Sph. angustifolium,* where the almost entire leaves occur toward the base and progressively more deeply lobed leaves toward the apex.

Lesquereux (1880, pl. 93, fig. 8) showed one branch only of a large specimen of *Sph. angustifolium* bearing a cone at its apex. The leaves of the lower part of this branch are narrowly 4-lobed or toothed and those of the upper part are bi-lobed. The type specimen from which Lesquereux's drawing was made (Lacoe Collection, U.S. National Museum, No. 18710) shows three orders of branches in organic connection. No leaves are present on the main or largest axis. The leaves on the first lateral branch are 4-lobed and grade into bifid leaves at its apex. Ultimate branches occur at the same nodes with leaves of this lateral branch and bear whorls of smaller leaves. Even on the ultimate branches, in a series of seven whorls of leaves, the range from more or less dissected leaves is seen. The basal whorl of leaves is composed of six more or less acutely toothed leaves, the next two whorls away from the base are 4-3 lobed, the next four whorls are 4-3-2 lobed, and the seventh and successive whorls are all bifid leaves.

Lesquereux (1858) described and figured *Sph. trifoliatum* in which the leaves are bi-trilobed, but two years later he transferred this species to *Sph. angustifolium.* In 1880, he described *Sph. bifurcatum* (Lacoe Collection, U.S. National Museum, No. 59) whose leaves are deeply bilobed and each of these lobes is again shallowly lobed or toothed. This specimen merely represents a median portion of the axis of *Sph. angustifolium.*

Jongmans (1911) correctly includes *Sph. trifoliatum* in the synonymy of *Sph. angustifolium,* but his figure 359 does not belong to *Sph. angustifolium.* This figure shows a trizygia leaf type with the leaves of a verticil of unequal length. In none of the American specimens of *Sph. angustifolium* or in available illustrations of European material have leaves of the trizygia type been observed.

Horizon and distribution.—United States: *West Virginia,* Randolph Co., Dry Fork District—Allegheny (WVA-G), Monongalia

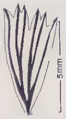
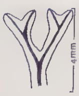
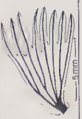
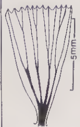
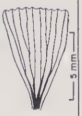
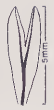
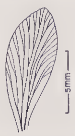
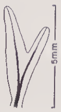
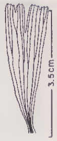
CHART 3	SPHENOPHYLLUM ANGUSTIFOLIUM GERMAR 1845	SPHENOPHYLLUM ARKANSANUM D. WHITE 1936	SPHENOPHYLLUM CORNUTUM LESQUEREUX 1876	SPHENOPHYLLUM CUNEIFOLIUM STERNBERG 1879	SPHENOPHYLLUM EMARGINATUM BRONGNIART 1822	SPHENOPHYLLUM FASCICULATUM (LX) D WHITE 1889	SPHENOPHYLLUM GILMOREI D. WHITE 1929	SPHENOPHYLLUM LESCURANUM D WHITE 1897	SPHENOPHYLLUM LONGIFOLIUM GERMAR 1828
No of leaves per whorl	6 (?4)	6	6	6 - 12	6	6 - 12	6	6	6
General outline	narrow elongate	broadly triangular	wedge, broadly cuneiform	wedge	wedge	narrow elongate	ovate to spatulate	narrow elongate	large elongate
Upper margin	straight 2 lobes split above middle	straight	arching 8 narrow lobes split to middle	arching dentate to lacinate	straight to arching	pointed, acute 2 lobes separated almost to base	convexly rounded	2 shallow lobes	arching 2-4 unequal lobes
Teeth	2-6 sharp	8 lobes 1 major cleft 2 minor clefts	none	8-12 mucronate	blunt	sharp - acute	entire to erose	2 - 4 rounded	sharp - acute
Sides	straight	concave	straight	convex to concave	straight to funnel-form	straight	convex	slightly convex	convex
Width	1 - 1.75 mm	major lobes-1mm	9-12 mm at middle	2-5mm	4-7mm	tapers to apex	4-8mm	1-1.75mm	1 cm
Length	3-5mm	4 mm	15-18mm	5-10mm	7-8mm	2.5-8mm	15-50mm	2-5mm	3cm
Veins entering	1	1	1	1	1	1	1(?)	1	1
Vein dichotomies	2-3	1	2	2-4	3-4	1-2	2-5	1	4-5
Stem width	2-3mm	1mm	4-5mm	1-5mm	.5-2mm	1-7mm branches freely	up to 8mm	2-3mm	2-4mm
Internode length	8-12mm	1-2 cm	3-4cm	7-20mm	7-15mm	1-6mm	12-80mm	5-12mm	1.5-3.5cm
Nodes	enlarged	moderately enlarged	enlarged	nlarged	slightly enlarged	enlarged	prominent	slightly enlarged	slightly enlarged
Diagram									

Chart 3. Species of *Sphenophyllum.*

Co., Cassville, and West Union, roof shales of Waynesburg Coal and 400′ above the Waynesburg Coal—Dunkard (WVA-S), near Core—Dunkard (WVA-G); *Ohio,* Meigs Co., Pomeroy, Pittsburgh Coal—Monongahela (WVA-C), Hocking Valley, shale over Pomeroy Coal—Monongahela (WVA-C), Athens Co., Kimberly, Upper Freeport—uppermost Allegheny (CINC-T); Jackson Co., Jackson—Pottsville (OU); *Kentucky,* Hazelgreen, Harmon Coal—Monongahela (CINC); *Pennsylvania,* Gate vein—Allegheny (US);

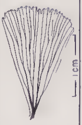
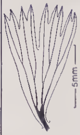
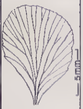
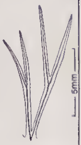
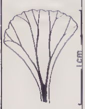
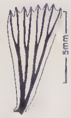
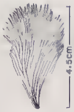
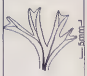
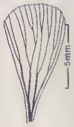
CHART 4	SPHENOPHYLLUM MAJUS BRONN 1828	SPHENOPHYLLUM OBLONGIFOLIUM GERMAR & KAULFUSS 1831	SPHENOPHYLLUM OBOVATAUM SELLARDS 1908	SPHENOPHYLLUM TENERRIMUM ETTINGSHAUSEN 1877	SPHENOPHYLLUM TENUE D WHITE 1900	SPHENOPHYLLUM TENUIFOLIUM FONTAINE & WHITE 1880	SPHENOPHYLLUM THONI MAHR 1868	SPHENOPHYLLUM TRICHOMATOSUM STUR 1887	SPHENOPHYLLUM VERTICELLATUM SCHLOTHEIM 1820
No. of leaves per whorl	6 - 9	6	6	6-9-12	6	6	6	6 - 8	6 - 9
General outline	large wedge	narrowly triangular	broadly obovate	elongate triangular	broadly cuneate	narrowly elongate	obovate	fan-shaped	narrowly triangular
Upper margin	straight to arching 2 - 4 lobes	arching	rounded	dichotomously lobed	rounded truncated	arching	highly arching	dichotomously lobed	arching undulated
Teeth	blunt varying	sharp-pointed varying	none	none	12-24 short broad, rounded	8 shallow	narrow, elongated spreading lobes	none	broad, blunt
Sides	convex	straight to convex	one straight one concave	straight to concave	strongly concave	convex	straight to convex	concave	straight to convex
Width	.5 - 1 cm	3 mm	8 - 10 mm	various	8 mm	1 - 2 mm	1.5 - 2 cm	3 mm	.4 - .5 cm
Length	2 cm	1 cm	10-15 mm	5 - 9 mm	1-2 cm	10 - 11 mm	3 - 5 cm	5 mm	1.2 cm
Veins entering	1	1	1(?)	1	1	1	1	1	1
Vein dichotomies	4 - 5	2 - 3	4 - 7	2	4 - 5	3	4 - 8	3	4 - 5
Stem width	1 mm	1.5 - 5 mm	2 mm	1 mm	1 - 3 mm	1 - 2 mm	5 mm	3.5 mm	5 mm
Internode length	2 cm	5 - 15 mm	10 mm	3-5 mm	1 - 5 cm	1 cm	2 - 4 cm	6.5 mm	8 - 10 mm
Nodes	slightly enlarged	slightly enlarged	prominent	prominent	slightly enlarged	prominent	enlarged	slightly enlarged	enlarged
Diagram									

Chart 4. Species of *Sphenophyllum* (continued).

Arkansas, Male's Coal and James Fork of Poteau—Allegheny (US); *Missouri,* Henry Co., near Clinton—Allegheny (US).

16. **Sphenophyllum arkansanum** D. White, 1936 Chart 3

Sphenophyllum arkansanum D. White, 1936, U.S. Geol. Sur., Prof. Paper 186-C:55, pl. 14, figs. 10, 12, 14, 19, 20.

Other references.—None.
Stratigraphic range.—Lower Pottsville.

The leaves, six in a verticil, are broadly cuneate in outline. They are bifurcate to one-half the length with the lobes again cleft. They are 2-3 mm. wide and 2.5-3 mm. long and are attached to the axis at approximately a right angle. The lateral margins of the leaves are concave. The central cleft is up to one-half to two-thirds of the length of the leaf and the two lateral clefts are shallow. A single vein enters the base of the leaf and branches dichotomously, once in the lower third of the leaf and again in the upper third of the leaf (Chart 3).

Internodes of the largest axes are 1-2 cm. long and 2.5 mm wide; those of the smaller axes are 6 mm. long and 1.5 mm. wide All nodes are slightly enlarged.

The type specimen, which is in two parts and carries the U.S. National Museum Nos. 39443 and 39444, shows flattened leaf whorls in which complete leaves may be seen. Other specimens, as noted by White (p. 55), contained various stem fragments bearing parts of leaves at the nodes. Preservation is poor and the leaves are almost the same color as the sandy matrix, but in strong reflected light, they clearly showed the venation pattern. No indication of epidermal cells could be seen. Nothing is known of the branching.

Sphenophyllum arkansanum with its four rounded lobes is distinct from *Sph. lescurianum,* which usually has only two, but may have three or four obtusely pointed lobes. (Compare diagrams on Chart 3). *Sph. arkansanum* is distinct from *Sph. trichomatosum,* since the latter is characterized by having four more or less equal lobes, each of which may again be shallowly cleft and sharply acuminate.

Horizon and distribution.—United States: *Arkansas,* Gillman, upper part of the Stanley shale—lower Pottsville (US). Known only from the United States.

17. **Sphenophyllum cornutum** Lesquereux, 1870
Pl. 44, figs. 66B, 68; Chart 3

Sphenophyllum cornutum Lesquereux, 1870, Geol. Sur. Illinois, IV, 2:421, pl. 19, figs. 1-5.

Other references.—Jongmans (1936, 1090-1091, bibliographic), Janssen (1939, 12-13, pl. 1, fig. 2b).

Stratigraphic range.—Allegheny to Monongahela.

The leaves, six in a verticil, have a fanlike symmetry with straight sides and slightly arching distal margin. They are deeply laciniate from one-third to one-half their length, forming eight or more, usually eight or nine, nearly equal, linear, spreading lobes (Pl. 44, figs. 66, 68). The leaves are 8-11 mm. wide at the base of the lobes. The lobes vary from 6-11 mm. long and 0.5-1 mm. wide and each lobe terminates in a mucronate tip. The total length of the leaf is 1-2 cm. A strong vein enters the base of the leaf (Chart 3) and immediately branches 2-3 times by more or less symmetric bifurcations. All subsequent bifurcations are completed before the veins reach the midportion of the leaf or enter the lobes. A single vein enters each lobe and continues without further division to form the apex of the lobe.

The thin-walled epidermal cells of both the lobes and the lamina are elongated in the direction of the long axis of the leaf, and the end walls are sharply inclined. Both lateral and end walls are undulate, with the long lateral walls thicker than the shorter end walls, giving the surface of the leaf a wavy, ribboned appearance in optical view. The cells forming the margins of the sinus between two lobes are irregularly rounded and extremely thick-walled (the same condition is seen in *Sph. oblongifolium,* Pl. 38, fig. 37). The cells which adjoin the veins are narrower than those near the margins of the leaf.

The larger stems (Pl. 44, fig. 66), quite stout in comparison to the stems of many other species of *Sphenophyllum,* are 4-5 mm. wide, and the internodes 3-4 cm. long. The nodes are slightly enlarged and are 6-7 mm. wide. Smaller stems may have internodes 1.5 cm. long and 3 mm. wide.

A study of transfer preparations, in which the venation of the leaf can be traced with accuracy (Chart 3), demonstrates that neither Lesquereux' account of 4-5 veins entering the leaf, nor Janssen's (1939) "correction" to but two veins, is correct. A single vein enters the base of the leaf, but since bifurcations take place immediately, this point is difficult or impossible to observe on the rock surface. But by the transfer method of observation, the occurrence of six leaves in a verticil was determined. It is possible that this number of leaves is not constant and certainly many verticils seem to exhibit but four or, for that matter, sometimes only two leaves, due to the plane of splitting on the shale. The number of lobes per leaf shows some variation, although eight is the most common number.

Janssen (1939) is quite correct in denying any affinity of *Sph. cornutum* with *Cingularia* where Jongmans (1936) had placed it in the synonomy of *Cingularia*. *Cingularia* is a fructification of uncertain affinity. *Sph. cornutum* is in no way connected with a fructification nor is it a part of a fructification. The relationships of *Sph. cornutum* probably lie, not with *Sph. cuneifolium* Sternberg as suggested by Janssen, but rather with *Sph. emarginatum* and will be considered in the discussion of that species.

Horizon and distribution.—United States: *Illinois,* Colchester, Morris Coal—Allegheny (cited by Lesquereux, 1870, and Janssen, 1939); *Ohio,* Kimberly, Athens Co., upper Freeport Coal—uppermost Allegheny (CINC-T); *Arkansas,* Allegheny and Washington Cos., Pittsburgh Coal—Monongahela (US).

18. **Sphenophyllum cuneifolium** (Sternberg) Zeiller, 1880
Pl. 37, fig. 22; Pl. 38, fig. 36; Chart 3.

Rotularia cuneifolia Sternberg, 1823, Essai d'un expose geognostico-botanique de la flore du monde, Leipsic et Prague, I, 2:33, 37, pl. 26, figs. 4a, b.

Rotularia saxifragaefolia Sternberg, 1826, Versuch einer geolognostisch-botanischen darstellung der flora der Vorwelt, I, 4:49, pl. 55, fig. 4, p. xxxii.

Sphenophyllum saxifragaefolium Geoppert, 1848, *in* Bronn, Index paleontologicus, Stuttgart, II:1166.

Spenophyllum erosum Dawson, 1868, Acadian Geology, 2d ed., London, p. 480, figs. 165 C, C_1.

Sphenophyllum cuneifolium (Sternberg), Zeiller, 1880, Végétaux fossiles du terraine houiller de la France, Paris p. 30, pl. 161, figs. 1-2.

Sphenophyllum myriophyllum Crepin, 1880, (in part), Société royale de botanique Belgique, XIX (2) :26.

Sphenophyllum gemma Matthew, 1910, Royal Soc. Canada, Trans., 3 (3) :96, pl. 6, fig. 7.

Sphenophyllum latum Matthews, 1910, Royal Soc. Canada, Trans., 3 (3) :95, figs. 5, 6.

Other references.—Jongmans (1936, 1092-1099, bibliographic), Arnold (1934, 184-185, pl. 2, figs. 2-4; pl. 3, fig. 6; pl. 4, figs. 3, 6), Bell (1938, 89, pl. 92, figs. 6-8; 90, pl. 93, figs. 4-6), Janssen (1939, 94, figs. 79b and d), Bell (1940, 129-130; 1944, 105-106, pl. 75, figs. 5-6; pl. 76, fig. 10), Arnold (1949, 185, pl. 18, figs. 1, 3, 5, 8, 9).

Stratigraphic range.—Pottsville to Monongahela.

The cuneate leaves, six in a verticil, are 5-15 mm. long and 2-10 mm. wide, with the distal margin straight to slightly arching and the lateral margins straight to slightly convex. The distal margin varies from dentate with sharply pointed teeth to deeply laciniate with sharply pointed lobes. The leaves near the apex of the axis are dentate and those occurring farther down on the axis are centrally and laterally cleft in progressively deeper clefts until four finger-like, sharply pointed lobes form the leaf (Pl. 37, fig. 22). A single vein enters the base of each leaf (Chart 3) and after two to four asymmetric dichotomous divisions one vein enters each tooth or lobe of the distal margin.

Internodes are 4-20 mm. long and 1-10 mm. wide and possess prominent nodes.

The cells of the abaxial epidermis (Pl. 38, fig. 36) average 8 mu wide and 42 mu long. They are elongated in the direction of the long axis of the leaf and are thin-walled, with the undulate lateral walls thicker than the highly inclined end walls.

The distal margin of the leaves in the apical region of the plant is sharply toothed. It becomes more and more dissected in a progressive series away from the apical region except possibly on branches which bear fructifications. A leaf may have only a central cleft up to 5 mm. in depth or a central cleft plus lateral clefts on either side of the central cleft. The distal margin of each of the resulting four lobes may have two or more acutely pointed teeth. These are of equal length in any given whorl but are of various lengths in different whorls. Further down on the axis or on larger axes, the depth of the central cleft is approximately 9 mm. or almost to the base of the leaf and that of the lateral clefts 5-8 mm. This results in a leaf of four slender finger-like lobes 0.5 mm. wide which taper to an acute apex. The lobes are usually divergent and generally increase the width of the leaf at its distal margin.

According to the depth of dissection, the leaves of *Sphenophyllum cuneifolium* have been given various specific names, *e.g., Sph. erosum, Sph. gemma, Sph. trifoliatum, Sph. latum, Sph. myriophyllum, Sph. costulatum, Sph. dichotomum,* and *Sph. saxifragaefolium.* As more complete specimens have been described, the various dissection types were found to belong to one species rather than to several.

A specimen from Kimberly, Ohio, shows an excellent series of variations in depth of dissection. One specimen, about 25 cm. long (shown in part in Pl. 37, fig. 22), bears on the lateral branches both dentate leaves of *Sph. cuneifolium* and laciniate leaves of *Sph. saxifragaefolium*, while the main axis bears the most dissected leaves of all, each of which consists of four long-tapering narrow lobes like those of *Sph. myriophyllum* Crepin. This type of lobed leaf has been figured many times by various authors. A figure by Stur (1887) for example, copied by Seward (1889), Kidston (1893), and Jongmans (1911), shows leaves of such diverse dissection that they were the basis for the statement that *Asterophyllites* and *Sphenophyllum* leaves occurred on the same axis. Kidston (1893) pointed out the error of this statement. Figures c and d on plate 56 by Renier (1910) show excellent examples of this extreme dissection in *Sph. cuneifolium.*

Isolated whorls of leaves of the *Sph. myriophyllum* type can not be attributed solely to *Sph. cuneifolium* since they also occur on other species. This has been shown in illustrations (Germar, 1844, pl. 6, fig. 3, and 1845, pl. 6, fig. 3, as well as in Jongmans, 1911, fig. 355) where they occur on larger axes which also bear leaves of *Sph. verticillatum* and *Sph. angustifolium.* Jongmans (1911) states that this lobed form of leaf is not clearly distinct from that of the European *Sph. angustifolium.* As there is no evidence that the leaf of the *Sph. myriophyllum* type occurs other than in association with *Sph. cuneifolium, Sph. angustifolium* or *Sph. verticillatum,* it cannot be considered a valid species in itself. *Sph. myriophyllum* is here reduced to synonymy.

Sph. cuneifolium is distinct from *Sph. verticillatum* in that the leaf has a more or less truncate distal margin and acutely pointed teeth, while that of *Sph. verticillatum* has a rounded distal margin and short blunt teeth. *Sph. angustifolium* is distinct from *Sph. cuneifolium* in that its leaves are more narrowly cuneate and sometimes only tri-lobed. The leaf of *Sph. cuneifolium* with its sharply pointed teeth is distinct from *Sph. emarginatum* since the latter has short blunt teeth.

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, 1000′ below the Tracey seam to the roof shales of the McRury seam or throughout the *Linopteris* zone—Pottsville (cited by Bell, 1938); Sydney Harbour, 100′ below the Black Pit seam or *Ptychocarpus* zone—upper Allegheny (cited by Bell, 1938); Pictou, Coal Brook (very rare) and Thorburn member of the Stellarton series—middle Allegheny (cited by Bell, 1940). United States: *Pennsylvania,* several mines near Cannelton, Stockton Coal—upper Allegheny (US), Plymouth, Orchard mine—Allegheny (US), Avaco, Brown's colliery—Allegheny (US); *West Virginia,* Saint Clair, Eagle mine, Eagle Coal or Kanawha—Pottsville (cited by White, 1895), Morris Creek, Cedar Grove, Handley, Riverside—middle Allegheny (cited by White, 1895); *Illinois,* Murphysboro, Zone 3—Pottsville (cited by Janssen, 1939), Mazon Creek—Allegheny (cited by Stewart, 1950); *Kentucky,* Perry Co., Blue Diamond mine, Hazard Coal No. 6—Pottsville (CINC), Christian Co., Crofton—Pottsville (CINC); *Michigan,* Grand Ledge, below cycle "A"—upper Pottsville (cited by Arnold, 1949), St. Charles, Big Chief No. 8 mine—Pottsville (cited by Arnold, 1949); *Ohio,* St. Clairsville, Pittsburgh Coal—Monongahela (cited by Lesquereux, 1880), Kimberly, Athens Co., upper Freeport—uppermost Allegheny (CINC-T), Lodi township, Athens Co., Pittsburgh Coal—Monogahela (CINC, CINC-T, OU), Athens Co., road cut near Albany, Kittanning Coal—middle Allegheny (CINC-T), Athens Co., near Buctel, Kittanning Coal—middle Allegheny (OU), McArthur, Vinton Co.—lower Allegheny (CINC-T), Power Run near Youngstown—horizon unknown (US); *Kansas,* Lansing, Cherokee shales, Cherokee stage—lower Allegheny, Thayer, Cahnute shales—upper Allegheny, Lawrence, LeRoy and Lawrence shales, Douglas group, lower Virgil—Monongahela (cited by Sellards, 1908); *Arkansas,* Washington Co.—Pottsville (US); *Missouri,* Lawrence Co., Aurora and McClelland's shaft—horizon unknown (cited by White, 1893).

19. **Sphenophyllum emarginatum** Brongniart, 1828
Pl. 38, figs. 29, 34; Pl. 44, fig. 66; Pl. 45, fig. 72; Chart 3.

Sphenophyllum emarginatum Brongniart, 1828, Prodrome, p. 68, Paris.
Sphenophyllum schlotheimii Lesquereux, 1880, Second Geol. Sur. Pennsylvania, Rept. Progress P, 1:52, pl. 2, figs. 6-7.

Other references.—Jongmans (1936, 1102-1109, bibliographic), Bell (1938, 89, pl. 93, figs. 1-3), Janssen (1939, 92, 94, figs. 79a, 80), Bell (1940, 130), Arnold (1949, 185, pl. 18, fig. 40).

Stratigraphic range.—Lower Allegheny to Monongahela.

Leaves, of equal length, six or nine in a verticil (Pl. 38, fig. 29), are 5-16 mm. long and 2.5-10 mm. wide. The sides are straight to concave and the distal margin is gently arched and may be entire but usually is finely dentate with obtusely rounded teeth, but it may or may not be further dissected. The distal margin when further dissected has a central cleft 2 mm. or more in depth, usually extending not more than one-half the length of the leaf, and two or more lateral clefts which are not so deep as the central cleft. The four lobes resulting from the clefts in the distal margin may also be finely dentate with obtusely rounded teeth. Leaves near the apex of the axis are less dissected than those near the base or those occurring on larger axes, so that there is a progression away from the apex of dentate to notched to deeply lobed leaves. A single vein enters the base of each leaf (Chart 3) and after three to four asymmetric dichotomous divisions, one vein enters each tooth where it becomes enlarged at the margin and appears as a submucronate tip.

The internodes are 7-15 mm. long and 0.5-2 mm. wide with the nodes slightly enlarged.

Cells of the abaxial epidermis (Pl. 38, fig. 34) average 10.5 mu wide and 57 mu long and are elongated in the direction of the long axis of the leaf. They are thin-walled with the undulate lateral walls thicker than the highly inclined end walls.

Sphenophyllum emarginatum occurs at a number of localities in America. As delimited by Zobel (1910), the species includes only those forms with leaves of equal length in a verticil. *Sph. verticillatum* is delimited from *Sph. emarginatum* since its leaves are unequal in a verticil, although there is a strikingly close resemblance of distal margin dissection.

Sph. emarginatum may, on occasion, have nine leaves in a verticil. This condition is rare but at least two specimens are known, one from Kimberly, Ohio, from the uppermost Allegheny and another (Pl. 38, fig. 29) from Clinton, Missouri, from the middle Allegheny (Lacoe Collection).

The leaves of *Sph. emarginatum,* as seen in Figure 66, Plate 44, show a progression series in the dissection of the distal margin from entire or dentate at the apex of the axes, to gradually deeper dissected leaves further away from the apex. All of the leaves of a single whorl are in the same stage of dissection. In the leaves which show the most dissection the lobes spread out or separate to such an extent that the width of the leaf at its distal margin is greatly increased.

From the dissection series displayed in the other species of the genus, the last probable step in the dissection series in *Sph. emarginatum* should be a leaf with eight symmetrical spreading lobes, such as seen in *Sph. cornutum.* However even after three summers of collecting from the strip mines near Kimberly, Ohio, where both species are numerous and occur together, no single specimen in which the two species were unquestionably organically connected was found.

Although leaves of both *Sph. emarginatum* (Pl. 44, fig. 66) and *Sph. cuneifolium* (Pl. 37, fig. 22) show dissection in a progressive series from entire leaves at the apex of the axis to deeply dissected leaves toward the base; the two are easily distinguished, as the teeth and lobes of all of the leaves of *Sph. emarginatum* (Chart 3) are obtusely rounded, while those of *Sph. cuneifolium* (Chart 3) are acutely pointed.

Again, *Sph. emarginatum* is distinct from *Sph. oblongifolium,* as this species has a trizygia leaf arrangement, and the leaves of *Sph. emarginatum* are all of equal length.

Numerous transfer preparations of this species were made, but none showed the abaxial epidermal stomatal structure because of the poorly preserved material. The epidermal cells of the abaxial surface are in longitudinal rows (Pl. 38, fig. 34). The cells are up to 65 mu long, the average is about 57 mu; the width of the cells also varies, but the maximum width between undulations is 13 mu and the narrowest about 8 mu with an average of 10.5 mu. The noticeable feature of these cells is their thin end walls which are inclined at a sharp angle from the vertical.

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, 200′ above the Tracey seam to the top of the Morien series at Point Aconi—Allegheny (cited by Bell, 1938), Pictou Coalfield, Thorburn member of the Stellarton series—Allegheny (cited by Bell, 1940). United States: *Michigan,* Grand Ledge, West Bay City, Cycle "F"—late Pottsville (cited by Arnold, 1949); *Pennsylvania,* throughout southern Anthracite Coal Field—lower, middle, and upper Allegheny (cited by White, 1900), Mohanoy City—horizon unknown (US); *West Virginia,* along the Kanawha River Basin, Stockton Coal and 300-400′ above the Black flint—upper Allegheny (cited by White, 1895); *Illinois,* Mazon Creek—upper Allegheny (CINC, and cited by Darrah, 1935), Braidwood—Allegheny (cited by Noé, 1925), Murphysboro, lower Des Moines—lower Allegheny (cited by Noé, 1925); *Kansas,* Lawrence, Leroy shales, Douglas stage—upper Conemaugh or lower Monongahela (cited by Sellards, 1908), Greene Co., Vicksburg mine, Des Moines—lower Allegheny (CINC); *Missouri,* Henry Co., Owens Coalbank and Pitcher's Coal bank—upper Allegheny (cited by White, 1899); *Ohio,* Athens Co., Kimberly, upper Freeport—uppermost Allegheny (CINC-T), Meigs Co., Pomeroy—Monongahela (OU), Athens Co., Lodi township—Monongahela (OU, CINC), Jackson Co., Jackson—Pottsville (OU), Athens Co., near Albany, Clarion Coal—Allegheny (OU), Athens Co., Trimble township, upper Freeport—uppermost Allegheny (OU); *Oklahoma,* McAlester—horizon unknown (US).

20. **Sphenophyllum fasciculatum** (Lesquereux) D. White, 1899
Pl. 37, figs. 25-28; Pl. 46, fig. 74; Pl. 48, fig. 84; Chart 3.

Asterophyllites fasciculatus Lesquereux, 1880, 2d Geol. Sur. Pennsylvania, Rept. Progress P, 1:41, pl. 3, figs. 1, 2.
Sphenophyllum fasciculatum (Lesquereux), D. White, 1899, United States Geol. Sur., Mon. 37:183-187, pl. 50, figs. 1-4.
Sphenophyllum fontinalis Round, 1927, Botanical Gazette, 83 (1) :65.

Other references.—None.

Stratigraphic range.—Allegheny.

Leaves, six in a verticil, are 1-4 mm. long (1-8 mm. ?) and 0.5-2 mm. wide. The leaves at the apex of an axis are bilobed from one-half to two-thirds the length of the leaf (Pl. 37, figs. 25, 27, 28), so that they often appear as 12 leaves in a verticil. These lobes are long-tapering, sharply pointed and erect falcate. The lower leaves (Pl. 37, fig. 27) are more or less reflexed and are further irregularly divided into 3 or 4 lobes. The length of the lobes decreases progressively downward on the axis, so that the lower leaves are often undissected and merely short lobed. The dissection of the leaves becomes progressively deeper from the base to the apex of the axis. A single vein enters the base of the leaf and divides to traverse each segment or lobe of the leaf (Pl. 38, fig. 41; Chart 3).

The branching is irregular with one or two branches at a node. They are flexuous to rigid (Pl. 37, fig. 27). The internodes are 1-3 mm. long at the apex and up to 10 mm. long on the older parts of the axis. The older axes (?) are 1 cm. in diameter with internodes 3 cm. long.

The original specimen of *Asterophyllites fasciculatus*, figured by Lesquereux (1878, Atlas, pl. 3, fig. 2) and now at the U. S. National Museum (No. 18292), is 14.5 cm. long, rigid in appearance and shows two ranks of branching with mostly opposite branches at a node. These branches form an angle of about 45° with the axis. Lesquereux's figure 1 does not show the leaves at the nodes bearing branches, although they are present. The larger axis is 4 mm. wide at the base, with internodes 1 cm. long, and decreases in width and internode length toward the apex. In the upper 6 cm. of the specimen (Pl. 48, fig. 84), the lateral branches are progressively shorter toward the apex, the longest being 2 cm. long with eleven whorls of leaves and the shortest 4 mm. with three whorls of leaves. At the apex of the larger axis as well as near the tips of the lateral branches, the leaves are small, about 1 mm. long and increase to 2.5 mm. long lower on the larger axes and near the bases of the lateral branches.

A second specimen, also identified and figured by Lesquereux (1878) as *Sph. fasciculatum*, figure 1, differs in the following respects: it is less rigid in appearance, the branching is not opposite, and the lateral branches ascend at a narrow angle. While this illustration would indicate that both branches and leaves are somewhat larger and stronger than those on the axis in figure 2, they are in fact approximately the same size.

D. White (1899, 183) in reviewing this species assigned it, although questionably, to the genus *Sphenophyllum*. He agreed that figures 1 and 2 of Lesquereux belonged to one species. In his redescription of the species, he stated that the length of the leaf varied from 2.5-8 mm. However, an isolated large axis 1 cm. wide with internodes some 3 cm. long occurs on the original specimen No. 18292 U. S. National Museum. At the nodes of this isolated axis the leaves are 8 mm. long, and while they are deeply lobed, the exact nature of the lobes could not be determined because of incomplete preservation. In all probability, White used this leaf measurement as the basis for his statement that the leaves occur as long as 8 mm. The size of the axis would indicate either a large species or an older and much larger stem. If the latter is true, then *Sph. fasciculatum* bore deeply dissected leaves on the largest axes.

Another specimen at the U. S. National Museum which White determined but did not figure or describe, bore three lateral branches each 14 cm. long, which were attached at regular intervals at an angle of 70°. These branches are more or less rigid; one branch is like the one on Lesquereux's plate 2, figure 2. The leaves are small, 1.5-2 mm. long and coincide with those of Lesquereux's description.

Material from McArthur, Ohio, (lower Allegheny) in plate 37, figures 25-28, has leaves up to 5 mm. long. The leaves are typically bifurcate near the tip of both the main and lateral branches and are 3 mm. long, 0.75 mm. wide. The form changes rapidly to irregularly bifurcated leaves lower on the axes (Pl. 37, fig. 26).

Specimens from Kimberly, Ohio, (uppermost Allegheny) have bifid leaves, some of which are falcate and very similar to those shown on White's figure 1. Associated branches, not attached to axes bearing characteristic leaves of *Sph. fasciculatum* and otherwise not identified, bear leaves with entire, four-toothed distal margins (Pl. 46, fig.74).

Since the dissection is less deep in all of the leaves borne on small axes, it would seem improbable that the deeply lobed leaves (8 mm. long) on the axes in association with type specimen No. 18292 actually belongs to the same plant. Again, the nature of the irregular lobing of the McArthur and Kimberly specimens seems to indicate that the entire (symmetrically toothed) leaves in association but not in connection do not belong to *Sph. fasciculatum*.

Horizon and distribution.—United States: *Pennsylvania,* Swartara Gap, Twin Coal—Allegheny (cited by White, 1900); *Missouri,* Henry Co., Owens Coalbank—Allegheny (US); *Ohio,* Athens Co., Kimberly, upper Freeport—uppermost Allegheny (CINC-T), Vinton Co., McArthur—lower Allegheny (CINC-T). Known only from the United States.

21. **Sphenophyllum gilmorei** D. White, 1929 Chart 3

Sphenophyllum gilmorei D. White, 1929, Carnegie Inst. Washington, Pub. 405:44-47, pl. 9, figs. 1-4; pl. 10, figs. 1-6; pl. 21, fig. 5.

Other references.—None.

Stratigraphic range.—Lower Permian.

The leaves, six in a verticil, are of equal length. They are ovate to spatulate, not crenate, widest at or a little above the middle, but narrowed toward the obtuse distal margin and toward the base. The distal margin is convexly rounded, entire, erose or faintly emarginate. Leaves at the apices of branches are 15 mm. long and 4 mm. wide; those lower on the axis or on larger axes are 50 mm. long and 8 mm. wide. The venation is generally obscure and according to Dr. White is "apparently fasciculate from the thickened base, forking 2-5 times at an extremely narrow angle in passing nearly erect, parallel, equidistant, and with slight outward curving to the border." The outermost or lateral veins end at the lateral margins approximately midway of the length of the leaf (Chart 3).

Axes are rarely branched and are up to 8 mm. in diameter with internodes 12-80 mm. long and the nodes prominent.

The type specimens in the U.S. National Museum indicate that this species is one of the largest of the genus both in length of leaf and in length of internode. D. White observed that the plant must have been at least three feet in height.

Another characteristic of this species is the shape of the leaf. The leaves are not cuneate as is the general rule for *Sphenophyllum* but are ovate to spatulate. In this respect they approach the situation seen in the longer leaves of a verticil in *Sph. speciosum,* a species readily distinguished from *Sph. gilmorei* by its trizygia pairing of the leaves. The leaves at the apex of the axis are somewhat broader in proportion to length than those further down the axis. White stated that the basal leaves also are short and ovate, although this kind was not among the specimens in the U. S. National Museum. The specimens from which he observed that "here and there along the stems densely placed, small verticils concealed the numerous relatively large sporangia" were not seen.

A third distinguishing characteristic is the venation pattern which is well illustrated by White (1929, pl. 10, fig. 2). It corresponds in general to that in *Sph. speciosum, Sph. verticillatum, Sph. obovatum,* and *Sph. thoni.* However *Sph. gilmorei* is clearly distinct from them by larger size and the form and arrangement of the leaves of a verticil. The venation pattern of *Sph. gilmorei,* because of the length of the leaf, gives the impression of close, parallel, rarely bifurcated veins; in fact, the veins bifurcate 2-5 times and in part arch toward the margin of the leaf.

Horizon and distribution.—United States: *Arizona,* Grand Canyon, Hermit shale—near top of the lower Permian (US). Known only from the United States.

22. **Sphenophyllum lescurianum** D. White, 1899 Chart 3

Sphenophyllum spp. D. White, 1897, Geol. Soc. America, Bull., 8:297.
Sphenophyllum lescurianum D. White, 1899, United States Geol. Sur., Mon. 37:182-183, pl. 50, fig. 6b; pl. 51, fig. b; pl. 24, fig. 3c.

Other references.—None.

Stratigraphic range.—Allegheny. Known only from the United States.

The leaves, six in a verticil, are narrowly cuneate, 3-5 mm. long and 1-1.75 mm. wide. The lateral margins of the leaves are slightly convex and the distal margin is generally cut by a central cleft into two blunt lobes. In the lower portion of some of the branches the leaves have additional lateral clefts which result in the formation of three or four more or less equal, obtusely pointed lobes. One vein enters the base of the leaf and divides dichotomously in the lower one-third of the leaf; when there are 3-4 lobes present, a second bifurcation occurs in the upper one-third of the leaf and one vein enters each lobe.

The slender axes branch freely and are marked by narrow, distant angular ribs.

D. White's type specimen, U. S. National Museum, No. 10874, shows three orders of branching. The largest axis is 3 mm. wide with one complete internode 3.5 cm. long. The largest branch from this axis is 1 mm. wide with internodes 5-6 mm. long; ultimate branches are 0.33 mm. wide with internodes 4 mm. long. The nodes on all three orders of branching are slightly enlarged.

The small size of the leaves and their notched distal margin (Chart 3) distinguish this species from other species of *Sphenophyllum. Sph. lescurianum* has been confused with *Sph. angustifolium* (under *Sph. angustifolium* var. *bifidum*), but it differs from this species not only in its small size but also in its rounded lobes. Leaves of *Sph. angustifolium* are more deeply lobed and the lobes are acutely pointed. Also in *Sph. angustifolium* the single vein which enters the base of the leaf bifurcates near the base. In *Sph. lescurianum* the single vein remains undivided for one-third to one-half the length of the leaf.

Horizon and distribution.—United States: *Missouri,* Henry Co., near Clinton—Allegheny (US). Known only from the United States.

23. **Sphenophyllum longifolium** (Germar) Geinitz, 1843

Pl. 45, figs. 70, 73; Chart 3

Sphenophyllites longifolius Germar, 1837, Isis von Oken, p. 426, pl. 2, figs. 2a, b.

Sphenophyllum longifolium (Germar), Geinitz, 1843, Gaea von Sachsen, p. 72.

Other references.—Jongmans (1936, 116-118, bibliographic), Janssen (1939, 94, fig. 79e).

Stratigraphic range.—Allegheny to Monongahela.

The leaves are large, 4-6 in a verticil, 2.5-4 cm. long and 0.8-1.3 cm. wide, longer than the internodes (Pl. 45, figs. 70, 73), and in many specimens overlapping. The lateral margins are more or less straight; the distal margin (Pl. 45, fig. 70) is essentially straight and bluntly toothed to laciniate in the upper one-fifth to one-third of the leaf. One vein enters the base of the leaf (Chart 3) and after 4-5 asymmetric dichotomous divisions a vein enters each of the teeth or lacinae of the distal margin.

The internodes range from 1.5-3.5 cm. long and 2-5 mm. wide, and the nodes are slightly enlarged. Definite ribs are lacking even on the shorter internodes.

The epidermal cells are narrow and elongated in the direction of the long axis of the leaf and the cell walls are undulate.

Coemans and Kickx (1864) stated that the leaves of this species may be up to 5 cm. long, but none of the American specimens are over 4 cm. long.

The available specimens show only 8-10 internodes, and there is little variation in the dissection of the distal margin on any one specimen. However, there were some more or less entire leaves in the collections which probably occurred toward the apex of the plant. Highly dissected leaves probably occurred toward the base.

According to Zobel (1910) and Zeiller (1906) the least dissected leaves are bifid to one-fifth or a little more of their length, and the resulting two segments or lobes are bluntly toothed. In the American specimens an average leaf dissection shows that each division of the bifid leaf is again asymmetrically cleft so that the distal margin is quite irregular. The lateral clefts may assume various depths but are as deep as the central cleft. The ultimate dissection is a deeply asymmetrically dissected leaf, well illustrated in Schimper (Atlas 1874, pl. 25, fig. 22).

A specimen (Chart 3) from Burgettstown, Pennsylvania, kindly loaned by Dr. A. J. Miklausen, shows leaves with more or less entire distal margins and Figure 70, Plate 45, another specimen from the same locality, shows the average amount of asymmetric division of the distal margin.

Jongmans (1911) commented that Lesquereux (1880, pl. 7, fig. 10 and 1884, pl. 91, fig. 6) showed leaves which are correct for this species; but felt that his figure 11 (1884) was probably *Sph. majus.* Jongmans might have come to this decision because of the amount of dissection shown in the leaf. The leaf exhibits greater dissection than those from Pennsylvania. I believe the leaf, in figure 11 (1884), because of its size and shape, is the extreme in the "dissection series" of *Sph. longifolium* and similar to that shown in Schimper, *l.c.*

Janssen recognized the species in the nodules from Mazon

Creek and illustrated the more or less typical leaf, *i.e.,* one of moderate dissection in his figure 79e. He stated that the central cleft extended to the middle of the leaf or beyond. He was incorrect in stating that four veins enter each leaf, since the specimens plainly show that only one vein enters (Chart 3), although two bifurcations are in close approximation to it. Where the leaf has been broken at that point or is buried in the enclosing matrix up to this point, it then appears as if four veins entered the leaf.

Since no transfer preparations were made from Dr. Miklausen's specimens, the details of the stomatal apparatus are not known.

Horizon and distribution.—United States: *Illinois,* Mazon Creek—Allegheny (cited by Janssen, 1939); *Pennsylvania,* Cannelton, Florence, and Burgettstown, Pittsburgh Coal—Monongahela (AJM); *Ohio,* Barnesville, horizon unknown (cited by Lesquereux, 1884); *Missouri,* near Clinton, Henry Co.—Allegheny (US); *West Virginia,* Cassville and West Union, roof shales of the Waynesburg coal—Monongahela (WVA-G).

24. **Sphenophyllum majus** (Bronn) Bronn, 1835
Pl. 37, fig. 23; Pl. 38, figs. 44-45; Pl. 46, fig. 75; Pl. 47, fig. 79; Chart 4

Rotularia major Bronn, 1828, *in* Bischoff, Kyptogamenflora Gewächse, 2:89, pl. 13, figs. 2a, b.

Sphenophyllum majus (Bronn), Bronn 1835, Lethaea geognostica, Stuttgart, 1:32, pl. 8, figs. 9a, b.

Other references.—Jongmans (1936, 1119-1121, bibliographic), Bell (1938, 90, pl. 94, figs. 1-2), Janssen (1939, 94, figs. 79c, 81), Bell (1940, 130), Arnold (1949, 185, pl. 18, fig. 7).

Stratigraphic range.—Pottsville to Dunkard.

The cuneate leaves, six in a verticil (Pl. 46, fig. 75), (eight according to Jongmans, 1911, and Bell, 1938) are from 1.2-2 cm. long and 0.5-1.3 cm. wide, and widest at the distal margin. The lateral margins are straight to convex. The distal margin is straight to slightly arching (Pl. 37, fig. 23) and vary in dissection from bluntly pointed and irregularly toothed to deeply laciniate. The central cleft of the distal margin may be shallow to 0.5-1 mm. or deep to one-half the length of the leaf. There may be pronounced lateral dissections of varying depths although the distal span or width is not increased by them. A single vein enters the base of the leaf (Pl. 37, fig. 23; Chart 4) and may bifurcate as many as five times before a vein enters a tooth or lacinia of the distal margin. The bifurcations are symmetrical, and the veins are relatively thin.

The internodes average 2 cm. long and 1 mm. wide, and the nodes are slightly enlarged.

The cells of both the abaxial (Pl. 38, fig. 44; Pl. 47, fig. 79) and adaxial epidermis are approximately 42-58 mu long and 8-14 mu wide, thin-walled, and elongated in the direction of the long axis of the leaf. The end walls diverge slightly from the vertical. Both the lateral and end walls are undulate. Stomata, limited to the abaxial surface (Pl. 38, figs. 44, 45; Pl. 47, fig. 79), are numerous and without a definite pattern of distribution. The stomatal apparatus (Pl. 38, fig. 45), elliptical in outline, 31 mu long and 22 mu wide, consists of two kidney-shaped guard cells and five or six accessory cells, the outer walls of which are undulate.

Jongmans (1911) illustrated a dissection series of the leaves of *Sph. majus* from Europe. The sharply dentate leaves are believed to occur at the apex of the plant and the more deeply dissected leaves toward the base. In American collections the cuneate leaves are sharply dentate and centrally, shallowly cleft. The leaves occur most frequently in isolated whorls; but in rarer instances where the leaves are attached to internodes, the leaves are up to 2 cm. long and 1 mm. wide and the nodes are enlarged. *Sph. majus,* due to its large size of 1.2-2 cm. in length and 0.5-1.3 cm. in width, is usually distinct from the other species of *Sphenophyllum.* Only three other species are conspicuously larger. The leaves of *Sph. longifolium* are often 2.5-4 cm. long and narrowly cuneate in form, whereas those of *Sph. majus* are only about one-half this length and broadly triangular in form. The leaves of *Sph. thoni* in its more or less entire leaf form may be as large as 3.5-4.5 cm. long and obovate in form, whereas those of *Sph. majus* are only about one-third this length and broadly triangular in form. The leaves of *Sph. gilmorei* are 1.5-5.0 mm. long and 4.8 mm. wide and obovate to spatulate and never cuneate in form, whereas those of *Sph. majus* are always cuneate in form.

Horizon and distribution.—Canada: *Nova Scotia*, Sydney Coalfield, throughout the uppermost zone of the Morien series—Allegheny (cited by Bell, 1938), Pictou Coalfield, Thorburn member of the Stellarton series—Allegheny (cited by Bell, 1940). United States: *Missouri*, Clinton, Henry Co., Owens Coalbank, Deepwater, Pitcher's Coal bank, Gilkerson's Ford—Allegheny (US); *Illinois*, Mazon Creek—Allegheny (cited by Noé, 1925 and Janssen, 1939); *Michigan*, Grand Ledge, below Cycle "A"—Pottsville (cited by Arnold, 1949); *Kentucky*, Crofton, Christian Co.—Pottsville (CINC); *Pennsylvania*, Perry Township, Green Co.—Dunkard (WVA-S).

25. **Sphenophyllum oblongifolium** (Germar and Kaulfuss) Unger, 1850
Pl. 38, figs. 33, 37, 42, 43; Pl. 44, fig. 69; Pl. 47, figs. 80, 81; Chart 4

Rotularia oblongifolium Germar and Kaulfuss, 1831, Nova Acta Academiae Caesareae Leopoldino-Carolinae naturae curiosorium, xv, 2:225, pl. 65, fig. 3.

Sphenophyllum oblongifolium (Germar and Kaulfuss), Unger, 1850, Genera et species plantarum fossilium, Vindobonae, p. 70.

Sphenophyllum filiculme Lesquereux, 1858, (in part), Geol. Pennsylvania, Government Sur., 2:853.

Other references.—Jongmans (1936, 1124, 1128, bibliographic), Bell (1938, 91, pl. 94, figs. 3-7; pl. 95, figs. 1-2), Janssen (1939, 96, fig. 79h).

Stratigraphic range.—Pottsville to Dunkard.

The narrowly obovate to cuneate leaves, six in a verticil (Pl. 44, fig. 69; Chart 4), are arranged in three bilaterally symmetrical pairs in each verticil. Two of the pairs are approximately at right angles to the axis, and the third pair is deflexed. The leaves are attached close together; but the leaves of a verticil are not evenly spaced around the node, with the result that a vacant arc of some 90° or more is left opposite the deflexed pair. The upper two pairs of leaves are of equal length, average 1 cm. long and 3 mm. wide, the deflexed pair is shorter, and average 5 mm. long and 2.5 mm. wide. All of the leaves are narrowly obovate, and widest in the middle with noticeably convex lateral margins. The distal margins are straight to slightly arching and variously toothed to lobed. Smaller axes bear leaves with short, acutely pointed teeth and may or may not have a shallow, central cleft. Leaves of larger axes are more deeply dissected by a median cleft and lateral clefts, so that the distal margin may be 4-lobed. The lobes may have as many as six, seven, or eight sharply pointed teeth of varying lengths. The shorter, deflexed pair of leaves is dissected and veined exactly as the others of a verticil. A single vein enters the base of each leaf (Pl. 38, fig. 43; Pl. 47, fig. 81, Chart 4) and immediately bifurcates twice. Other bifurcations may occur at approximately the mid-portion of the leaf, and a single vein enters each tooth and terminates in the mucronate apex.

The internodes are 5-15 mm. long and 1.5-5 mm. wide with the nodes slightly enlarged. The axes are sparingly branched and bear 1-2 lateral branches at each node.

The cells of the abaxial epidermis are elongated in the direction of the long axis of the leaf (Pl. 38, fig. 42; Pl. 47, fig. 81). They average 100 mu long and 15 mu wide (Pl. 38, fig. 33), are thin-walled, with the lateral and highly inclined end walls undulate. The cells at the base of the clefts (Pl. 38, fig. 37) are small, almost as broad as long, and have thick walls. Away from the immediate area of the cleft, the cells are more elongate and typical of those described above. Cells along the veins and along the margin of the leaf are approximately the same size as those toward the interior of the lamina.

The leaves of *Sph. oblongifolium* form a dissection series, dentate to deeply lobed, similar to those in *Sph. cuneifolium* and *Sph. verticillatum.* According to Coemans and Kickx (1864), Zeiller (1880, 1892, 1906), Zobel (1910), Jongmans (1911), and Halle (1927), the entire leaves and those with a central cleft are borne on lateral branches or apices of larger axes and the deeply lobed leaves are borne on larger axes. The American specimens are dissected up to one-half their length, therefore, they are not so deeply dissected as those from Europe.

Sph. oblongifolium with its trizygoid leaf arrangement is distinct even in its deeply laciniate forms from *Sph. cuneifolium* and *Sph. angustifolium* since the leaves of the latter species are all of equal length. *Sph. oblongifolium* is similar to *Sph. speciosum* in leaf arrangement but is quite distinct since its leaves average 1 cm. in length, and those of *Sph. speciosum* average twice that length.

Some specimens (HBL) from the type locality, which were identified and labeled *Sphenophyllum filiculme* by Lesquereux, agree with *Sph. oblongifolium* in leaf arrangement, shape, size, and venation. Other specimens (HBL), which were also labeled *Sph. filiculme* by Lesquereux, do not agree exactly, although they might be considered a variety of *Sph. oblongifolium.*

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, roof shales of Harbour seam (rare) but abundant at top of Morien series—Allegheny (cited by Bell, 1938), Pictou Coalfield, Thorburn member of Stellarton series—Allegheny (cited by Bell, 1940). United States: *Kansas,* Blue Mound, Chanute shale, Kansas City group—upper Monongahela (cited by Sellards, 1908); *Illinois,* Murphysboro, lower Des Moines—lower Allegheny (cited by Janssen, 1939), Mazon Creek—Allegheny (cited by Darrah, 1935, and Janssen, 1939); *Missouri,* Henry Co., near Clinton—Allegheny (cited by White, 1899); *West Virginia,* Cassville and West Union, Waynesburg Coal—top of Monongahela (WVA-G), Brewery beds and Salem beds—Pottsville (WVA-G), Mason Co., Letart, Letart Power Plant Zone, Washington series—Dunkard (WVA-S), Monongalia Co., Cass District, Waynesburg—top of Monongahela (WVA-S), near Kempton, mostly in Granite Co., Pittsburgh Coal—Monongahela (WVA-S); *Pennsylvania,* Cannelton—Allegheny (US), Green Co., Perry township—Dunkard (WVA-S), Green Co., Dunkard township, Waynesburg Coal—top of Monongahela (WVA-S), Fayette Co., German township, Gate's Mine, Pittsburgh Coal—Monongahela (WVA-G), Burgettstown, roof shales of Pittsburgh Coal—Monongahela (AJM), Salem seam at Pottsville—lower Allegheny (US); *Ohio,* Athens Co., Kimberly, Upper Freeport—uppermost Allegheny (CINC-T), Lodi township, Pittsburgh coal—Monongahela (WVA-C, CINC, CINC-T, OU), Meigs Co., Pomeroy—Monongahela (WVA-C), Munroe Co., Ohio township, Washington "A"—Dunkard (WVA-C), Athens Co., Bern township, Waynesburg roof shales, Cassville—Dunkard (WVA-S), Munroe Co., near New Martinsville, along O'Possum Creek, Washington "A"—Dunkard (WVA-C), Jackson Co., Jackson—Pottsville (OU), Athens Co., near Albany, Clarion Coal—Allegheny (OU).

26. **Sphenophyllum obovatum** Sellards, 1908
Pl. 38, figs. 32; Pl. 44, fig. 67; Chart 4.

Sphenophyllum obovatum Sellards, 1908, Univ. Geol. Sur., Kansas, 9:456-458, pl. 61, figs. 17, 18; pl. 64, fig. 4.

Other references.—None.

Stratigraphic range.—Permian.

The broadly obovate leaves, six in a verticil (Pl. 44, fig. 67), are 3-5 mm. long on the apical part of an axis, the largest 10-15 mm. long and 8-10 mm. wide, widest at or near the middle. The lateral margins are entire, short and slightly concave. The distal margin is broad, rounded, extends to about half of the length of the leaf, and is inconspicuously blunt toothed. The distal margin usually extends further toward the base of the leaf on one side than on the other and the leaf is asymmetrical. One (?) vein enters the base of the leaf (Pl. 38, fig. 32) and after 4-7 irregular dichotomous divisions, 25-28 veins reach the distal margin; the lower veins strongly arch before reaching the margin at or near the middle of the leaf.

Internodes are from a few millimeters to 1 cm. long and 1 mm. wide at or near the apices of small axes; on larger axes they are up to more than 4 cm. long and 6 mm. wide with the nodes enlarged.

Preservation was so poor that a transfer could not be made, and nothing is known of the epidermal pattern and stomatal organization.

The above description includes information, not only from the observations of Sellards in the original description of the species, but also from a study from one of his original specimens and shown in his plate 61, figure 17. This specimen, No. 5368, kindly loaned by Dr. R. W. Baxter from the University of Kansas Museum Collection (Pl. 44, fig. 67), consists of a small axis with two internodes and parts of three whorls of leaves. The internodes are 10 mm. long and 2 mm. wide with the nodes enlarged to 3 mm. Sellard's figure 17 shows only four leaves in the verticil, but he illustrated the central one of the three whorls which are present. This one is crowded in part by the leaves of the whorl below, in which there are six leaves as figure 67, Plate 44 indicates. There is no reason to suppose that any of the verticils of this species consisted of only four leaves.

Sellards noted that, although the leaves vary in size on different parts of the plant, their shape and form is consistent. The form of the leaf, as well as that of the verticil, is distinct. In most species of *Sphenophyllum* the leaves are symmetrical and the verticil is symmetrical. *Sph. obovatum* is different from other species in that the two sets of three leaves in the verticil are mirror images of each other. The general effect is one of a vertically divided verticil composed of three asymmetric leaves. The lower lateral margin of the leaf is slightly longer and less concave than the upper margin.

The basal portion of the leaf is narrow, approximately 1 mm. near its attachment, and in this it agrees with most species of the genus. However, in *Sph. obovatum*, the leaf appears to be stalked due to the concave lateral margins and the rapidly expanding width of the leaf (8 mm. near the middle).

The actual point of attachment of the leaf to the axis is difficult to observe. The arrangement of the verticil indicates that the leaves probably were attached to the axis at an acute angle, and then curved away from the node to lie in a plane perpendicular to the axis. In all of the specimens, the leaves are either broken or folded 0.3-0.5 mm. from their point of attachment. Apparently only one vein entered a leaf. However, in only one leaf of the type specimen could the presence of as few as two veins entering the leaf base be established; other leaf bases are broken further back so that three or four veins are present. In transfer preparations of many other species of *Sphenophyllum* only one vein enters the base of the leaves and, depending upon the species, the single vein may bifurcate immediately or remain undivided for as much as 1 mm. before subdividing. Subsequent bifurcations may be at some distance, again depending upon the species. It is probable that only one vein entered the base of the leaves of *Sph. obovatum* also and that it divided on leaving the node to produce the two veins on the fractured edge of the leaf base. Divisions of these two veins continue until a total of about seven bifurcations have taken place by the time the veins reach the top of the leaf. There may be as few as three bifurcations along the margins of the leaf.

Sellards noted that this species is abundant in the Chase formation and in the Wellington shales. In a large axis 20 cm. long the internodes were 4 cm. long and 6 mm. wide, with no increase in width to the apex. He also noted that the larger axes bore one branch at a node "partly below but mostly above" the node (see Sellards' text figure, p. 457) and that these axes were devoid of leaves. There may have been leaves which were either deciduous or lost in some manner.

Sphenophyllum obovatum has been compared to the smaller leaved form of *Sph. thoni* from Europe and China. The asymmetric nature of the leaf, and the round and blunt teeth of the distal margin of *Sph. obovatum* are in sharp contrast with the symmetric leaf and pronounced acute teeth of the distal margin of *Sph. thoni.*

Sph. gilmorei is somewhat similar in leaf form, but the leaves are ovate to spatulate rather than broadly obovate, and the lateral margins are convex rather than concave. Also, *Sph. gilmorei* is a larger form with the leaves up to 5 cm. in length, while in *Sph. obovatum* they are only 1.5 cm. in length.

Horizon and distribution.—United States: *Kansas,* Banner City, Dickinson Co., Wellington shales—Permian (mid-Continent) and near Washington, Chase formation—Permian (in the University of Kansas Museum). Known only from the United States.

27. **Sphenophyllum tenue** D. White, 1900 Chart 4

Sphenophyllum tenue D. White, 1900, United States Geol. Sur. 20th Ann. Rept., 2:900-901, pl. 191, figs. 6, 7.

Other references.—None.

Stratigraphic range.—Pottsville.

The leaves, six in a verticil, are 1-2 cm. long, 8 mm. wide and widest near the distal margin. They are broadly cuneate with slightly to strongly concave lateral margins and taper to a long, slender, stalklike, somewhat thickened base. The distal margin is slightly to strongly arching, crenulo-dentate with 12-24 short, broad, rounded or obtuse teeth, or more rarely with two, more or less dissected, broad, obtuse, usually bi-tridentate lobes. A single vein enters the base of the leaf (Chart 4) and divides dichotomously 4-5 times before a vein enters a tooth of the distal margin.

The ridged axes have internodes 1-5 cm. long and 1-3 mm. wide with the nodes only slightly enlarged. The axes branch freely, with one to three branches at a node.

Chart 4 shows a broadly cuneate leaf, with crenulate-denticulate, rounded distal margin, conspicuous concave lateral margins and a tapering long slender base. Of the many specimens observed at the U.S. National Museum from various localities, including the type specimen, Number 18500 in the Lacoe Collection which was figured by White on plate 191, figure 6, most showed the type of leaf just described. A dissected type also occurs. This type is divided into lobes by a shallow central cleft up to one-third of the length of the leaf, and by additional lateral clefts. The lobes are broad, obtuse, of irregular length, and each is bi- or tridentate.

Sph. tenue is distinguished from *Sph. majus* by the rounded distal margin, the concave lateral margins, and stalked base of the leaves. *Sph. tenue* is similar to *Sph. obovatum* in the rounded distal margin and the concavity of the lateral margins of the leaves. In *Sph. tenue* the distal margin continues down the sides of the leaf for less than one-fourth of the length of the leaf, whereas, in *Sph. obovatum* the distal margin is unevenly continuous down the lateral margins, *i.e.,* it extends further down one side than the other. Also in *Sph. obovatum* the six leaves in a verticil are arranged in two opposite groups of three each (Pl. 44, fig. 67), while in *Sph. tenue* the six leaves are equally spaced.

Horizon and distribution.—United States: *Pennsylvania,* Pottsville Gap, New Lincoln Mine, Brookside and Lincoln Collieries, Kimble Drift and the Northside shaft, all Lykens coal No. 4—mid-Pottsville (US); *Alabama,* Sydneyton and New Castle—Pottsville (US). Known only from the United States.

28. **Sphenophyllum tenerrimum** Ettingshausen, 1877
Pl. 48, figs. 82, 83; Chart 4.

Sphenophyllum tenerrimum Ettingshausen, *in* Stur 1877, Abh. K. K. geol. Reichsanstalt, Wien, Abh. viii, 2:108, pl. 7, text-figs. 21-24.

Other references.—Jongmans (1936, 1142-1144, bibliographic), Lesquereux (1884, 728-729, pl. 92, figs. 9-10a).

Stratigraphic range.—Pottsville.

The leaves, 6, 9, or 12 in a verticil, are from 5-7.5 mm. to (exceptionally) 9 mm. long, and once or twice bifurcate into 3-6 linear lobes or lacinae 0.25-0.33 mm. wide and 5-6 mm. long. The leaf may be dissected to slightly above the middle, to the middle, or to the base of the leaf. Entire leaves are unknown. The leaves are united at their bases by a sheath which may be as much as 1 mm. wide. Toward the apices of branches the leaves are erect and somewhat incurved at the tips. On the lower part of the branches, and on larger axes, the leaves are at approximately right angles to the axis. A single vein enters the base of the leaf (Chart 4) and divides dichotomously once to three times with one veinlet entering each lobe.

The ribbed internodes on larger axes are 2 cm. long; on lateral branches 3-5 mm. long and 1 mm. wide. The nodes are enlarged and prominent.

This species bears leaves which are dissected into long, linear or filamentous lobes. An isolated verticil of leaves is occasionally found spread out on the shale matrix so that its habit, venation, and number of leaflets can be determined (Pl. 48, fig. 83), but this condition of preservation is not typical, and the lobes are usually twisted or may overlap. This is the condition seen on the type specimen of Lesquereux from Rushville, Ohio, at the U.S. National Museum. While the leaves are only of approximately equal length in the verticil, they are not trizygoid in arrangement as are those in *Sph. oblongifolium.*

Sph. tenerrimum is separated from *Sph. trichomatosum* by minor but distinct differences. *Sph. tenerrimum* has leaves wtih acute lobes, while *Sph. trichomatosum* has leaves with broad emarginate lobes. The lobes of *Sph. tenerrimum* are linear; longer and narrower than those of *Sph. trichomatosum.*

Horizon and distribution.—United States: *Ohio,* Rushville, Waverly formation (?)—Pottsville (US); *Alabama,* Pratt Mine near Birmingham, Coalburg, near Gasden—all Pottsville (US).

29. **Sphenophyllum tenuifolium** Fontaine and White, 1880
Pl. 46, fig. 77; Chart 4

Sphenophyllum tenuifolium Fontaine and White, 1880, Second Geol. Sur. of Pennsylvania, Rept. Progress, p. 38, pl. 1, fig. 9.

Other references.—Jongmans (1936, 1144, bibliographic), Janssen (1939, 94, 96, figs. 79f, 82).

Stratigraphic range.—Monongahela.

The leaves, six in a verticil (Pl. 46, fig. 77), are equal in length, narrowly elongate-cuneate and 1-2 mm. wide and 7-16 mm. long. In each verticil there is a group of three leaves on each side of the axis. The groups are arranged so that there is an angle of approximately 90° between the groups toward the apex of the axis and approximately 145° between the groups toward the base of the axis. The lateral margins of the leaf are straight to slightly convex, and the distal margin is straight to slightly arched and shallowly dentate with as few as four to as many as eight sharp teeth. Leaves near the apex of an axis are not divided, but the leaves on the branches have a central cleft 1 mm. in depth and two shorter lateral clefts, resulting in an unequally 4-lobed leaf. The lobes end in one or two sharply pointed teeth (Pl. 46, fig. 77). One vein enters the base of the leaf (Chart 4) and dichotomises 2-4 times before reaching the teeth of the distal margin.

The internodes are 10-12 mm. long and 1 mm. wide and the nodes are slightly enlarged.

Sph. tenuifolium more closely resembles *Sph. angustifolium;* in the latter the teeth of the leaves are rounded and blunt, while the former has sharply pointed teeth. Further, in *Sph. angustifolium,* all forms of leaves in the dissection series may be seen on a branch less than 10 cm. in length, or in 10-12 consecutive internodes. In *Sph. tenuifolium,* on a branch of similar length and number of internodes, the leaves are unchanged in size and dissection. *Sph. tenuifolium* does not have a trizygoid leaf habit and is therefore, distinct from species bearing leaves of unequal length but of similar form, *e.g., Sph. oblongifolium.*

Horizon and distribution.—United States: *West Virginia,* Cassville and West Union, Waynesburg Coal—upper Monongahela

(WVA-G), near Kempton, mostly in Granite Co., Pittsburgh Coal—Monongahela (WVA-S). Known only from the United States.

30. **Sphenophyllum thoni** Mahr, 1868
Pl. 38, fig. 39; Pl. 45, fig. 71; Pl. 46, fig. 76; Chart 4

Sphenophyllum thoni Mahr, 1868, Zeitschrift Deutsch. Geol. Geschichte, 20:433, pl. 8, figs. 1-4.

Sphenophyllum thoni var. *minor* Sterzel, 1895, Mitteilungen der Grotberzogl. Badischen Geol. Landesanstalt, III, 2:322-324, pl. 10, figs. 26-27, pl. 11, figs. 1-4.

Other references.—Jongmans (1936, 1144-1146, bibliographic).

Stratigraphic range.—Monongahela.

The leaves, six in a verticil, are obovate and of equal length. They are 3-5 cm. long and 1.5-2 cm. wide, widest above the middle of the leaf. The lateral margins are straight to slightly concave and the distal margin is rounded (Pl. 38, fig. 39; Pl. 46, fig. 76). It often extends down to or below the middle of the leaf, and is usually deeply lobed or laciniated but may be entire. The length of the lobed or fringed portion is 3-6 mm., and each linear division is about 0.5 mm. wide. The lobes or laciniae are spreading with a few, approximate or overlapping (Pl. 38, fig. 39; Pl. 46, fig. 76). A single vein enters the narrowed base of the leaf and branches by bifurcations 4-8 times. Some of the lower veins curve before reaching the apices of the lobes of the distal margin.

The internodes are 2-8 mm. long and 3-6 mm. wide and the nodes are enlarged (Pl. 45, fig. 71).

The epidermal cells as seen under reflected light are narrow and elongated in the direction of the long axis of the leaf. The cell walls are undulate.

The leaves of the material of *Sph. thoni,* kindly loaned by Dr. A. J. Miklausen, are all of the fimbriate or fringed type of leaf. The leaves are commonly widest just above the mid-portion, but they may be wider just below the apex of the leaf. The distal margin is dissected into as many as 40-50 lobes or laciniae, and the lobes may spread so that the width of the leaf is increased as much as 1 mm., particularly in the most dissected leaves. The lobes are linear and may be as wide as 0.5 mm. although they may be narrower.

The general consensus of opinion in the past has been that more than one vein enters the base of the leaf, however, specimens from Pennsylvania (Pl. 38, fig. 39; Pl. 46, fig. 76) show that one vein enters and immediately bifurcates twice.

Since no transfer preparations were made, the details of the stomatal apparatus are not known.

The species *Sph. thoni* was based upon leaves with the distal margins laciniated or fringed. Later, Zeiller (1892) observed that smaller leaves occurring on smaller axes were not laciniate but were acutely toothed at the distal margin. Sterzel (1895) also noted this fact and proposed a variety name—var. *minor* for the entire leaves. In both leaf types, the veins follow a similar diverging course toward the distal margin and bend toward the sides of the leaf. Both Zobel (1910) and Jongmans (1911) believed that since the two leaf types had been found on one plant (Zeiller, 1892) the var. *minor* should be reduced to synonymy. Halle (1927), in his "Plants from Central Shansi", although recognizing that this plant bore two types of leaves, as Zeiller had indicated, considered that some of the isolated leaf whorls were distinct from those of Zeiller's plant and more closely resembled *Sph. thoni* var. *minor* as originally described and figured by Sterzel (1895). He recognized this variety which he described as having a leaf 1) as large as the fimbriate leaves of *Sph. thoni* and larger than the usual entire-leaved form; 2) with an entire distal margin, diverging venation, and more pronounced triangular shape; and 3) occurring not only in the same horizons together with *Sph. thoni* in the lower Shihhotse series, but also in the upper Shihhotse series where *Sph. thoni* had not been noted. Halle gave a leaf length of 1.5-3 cm. for his variety from China, which is smaller than that of the Pennsylvanian specimens, which are 3-5 cm. long and occur relatively high in the stratigraphic column of the Monongahela.

Sph. thoni is larger than any other Carboniferous species with the exception of *Sph. gilmorei* which occurs in the Permian of Arizona. Leaves of both species may reach a length of 5 cm.; however, they differ greatly in width of the leaves since the leaves of *Sph. thoni* are 15 mm. wide, and those of *Sph. gilmorei* are only 6-8 mm. wide.

Horizon and distribution.—United States: *Pennsylvania,* near Burgettstown, above the Pittsburgh Coal—Monongahela (AJM).

31. **Sphenophyllum trichomatosum** Stur, 1887 Chart 4

Sphenophyllum trichomatosum Stur, 1887, K. K. Geol. Reichsanstalt, Wien, Abh. xl, 2:202, pl. 15, figs. 1, 4.

Other references.—Jongmans (1936, 1147-1148, bibliographic), Bell (1938, 90, pl. 93, figs. 7-8).

Stratigraphic range.—Pottsville to Monongahela.

The leaves, mostly nine in a verticil, are 5-13 mm. long, and are two to three times dichotomously divided and fan-shaped. The 4-6 linear lobes are 0.5 mm. wide, and the broad apices are emarginate to bluntly 2-toothed. The base of the leaf is broad. One vein enters the base of the leaf (Chart 4) and divides dichotomously two or three times and a single vein goes to each tooth. The leaves are as long or slightly longer than the internodes and form a wide angle to 90° with the axis.

The axes are 0.5-3.5 mm. wide, with internodes 4-7 mm. long. and the nodes are slightly enlarged. They are ribbed and the surface is finely punctate.

The number of leaves in a verticil varies from six to nine in the specimens from Pennsylvania and Ohio. Jongmans' figure 396 (1911) indicates eight leaves occurring in a verticil. Bell, page 90, stated that there were up to eight leaves in a verticil in the Canadian specimens.

Sph. trichomatosum is similar to *Sph. tenerrimum* in that they both bear only deeply segmented leaves. *Sph. trichomatosum* is separated from *Sph. tenerrimum* by having leaves with broad emarginate lobes, while the leaves of the latter species has lobes which are linear, longer, and narrower than those of *Sph. trichomatosum.*

Horizon and distribution.—Canada: *Nova Scotia,* Sydney Coalfield, 50′ above the Tracey seam, and roof of Mullin's seam—Allegheny (cited by Bell, 1938), Backpit seam—upper Allegheny (cited by Bell, 1938). United States: *Pennsylvania,* Pottsville Gap, below the Twin Coal and at Lincoln, upper Lykens division, coals 2 and 3—Pottsville (cited by White, 1900); *Ohio,* Athens Co., Lodi township, Pittsburgh Coal—Monongahela (OU).

32. **Sphenophyllum verticillatum** (Schlotheim) Zeiller, 1885
Pl. 38, figs. 30, 31, 38; Chart 4

Palmacites verticillatus Schlotheim, 1820, Die Petrefactenkunde auf ihrem jetzigen Standpunkte, Gotha, p. 396.
Sphenophyllum verticillatum (Schlotheim), Zeiller, 1885, Société Geol. de France, Bull. (3) XIII: 140, pl. 8, fig. 4.

Other references.—None.

Stratigraphic range.—Allegheny to Monongahela.

The cuneate leaves, six in a verticil (Pl. 38, fig. 30), are 8-15 mm. long and 4-6 mm. wide and widest at the distal margin. The leaves on a node are anisophyllous with the longest pair at the top of the verticil, the intermediate pair in the middle, and the shortest pair deflexed. The leaves are attached close together; but the leaves of the verticil are not evenly spaced around the node, with the result that a vacant arc of some 140-145° is left opposite the deflexed pair. All of the leaves have lateral margins straight to convex, and the distal margin half turbinate or rounded. It may be variously dissected. The dissection series varies from leaves which are obtusely dentate on small branches and apices of larger branches, to those with a central cleft and finally to those deeply dissected or 4-lobed on larger axes. A single vein enters the base of each leaf (Pl. 38, figs. 31, 38; Chart 4) and branches dichotomously 2-5 times before a vein enters a tooth or lobe of the distal margin.

The internodes are slender, flexuous, striated to deeply furrowed, and 8-15 mm. long and 1-4 mm. wide, with the nodes slightly enlarged.

The cells of the abaxial epidermis average 10 mu wide and 50 mu long, and are thin-walled, with the undulate lateral walls thicker than the highly inclined end walls. They are elongated in the direction of the long axis of the leaf.

Sph. verticillatum is unusual because of the anisophyllous condition of the three pairs of leaves in each verticil. Figure 30, Plate 38, (a promar projection tracing of slide No. K#3 CINC-T) shows four complete whorls of leaves on an axis. There are three pairs of leaves in a verticil, and the opposite pairs are similar with the leaves of a pair of unequal length. The upper leaf is 12 mm. long and 6 mm. wide, while the lower leaf is 10 mm. long and 6 mm. wide. The deflexed pair of leaves is 9 mm. long and 5 mm. wide. Other specimens show variation in size, but the three pairs of leaves are in the same proportion.

The leaf whorls of *Sph. verticillatum* are similar to those of *Sph. oblongifolium* in that each is trizygoid in habit. They differ in that the lateral pair of leaves of a whorl in *Sph. oblongifolium* are the same length, while the lateral leaves of a pair in *Sph. verticillatum* are of unequal length. Leaves of *Sph. verticillatum* have bluntly rounded teeth and those of *Sph. oblongifolium* have sharply pointed teeth (Compare figs. 31 and 43, Pl. 38).

Figures 31 and 38, Plate 38, show that only one relatively heavy vein enters the base of each leaf, a condition found in all of the species. This is in agreement with Zobel (1910). Jongmans (1911) stated that as many as 3-4 veins entered the base of the leaf. He used this characteristic as a basis for including several species under the synonoymy of *Sph. verticillatum.* Since the point of attachment of any leaf is often lost in preservation, and since the early bifurcations take place so close to the point of attachment that when the latter is broken, several veins "appear" to enter the leaf, it would seem that the character of the number of veins entering a leaf is not a good diagnostic character.

The leaves of *Sph. verticillatum* are similar to those of *Sph. emarginatum* in that both have an obtusely dentate distal margin. They differ markedly in that *Sph. emarginatum* has leaves of equal length symmetrically arranged and equally spaced around the node, while the leaves of *Sph. verticillatum* are anisophyllous.

Horizon and distribution.—United States: *Missouri,* Henry Co., near Clinton—lower Allegheny (US); *Illinois,* Mazon Creek—Allegheny (US, CINC); *Ohio,* Athens Co., Lodi township, Pittsburgh Coal—Monongahela (OU, CINC), Athens Co., Kimberly, upper Freeport—uppermost Allegheny (CINC-T), Athens Co., near Albany, Clarion Coal—Allegheny (OU); *Pennsylvania,* Beaver Co., Cannelton, Kittanning—middle Allegheny (US).

DOUBTFUL AND EXCLUDED SPECIES

1. **Sphenophyllum filiculme** Lesquereux

Sphenophyllum filiculme Lesquereux, 1858, Geol. Pennsylvania, Government Survey, 2 : 837.

The type specimen of *Sph. filiculme* is not available for study, and the illustration of the type (pl. 1, fig. 6) is not adequate for identification purposes.

Dr. E. S. Barghoorn, Harvard Biological Laboratories, kindly loaned me specimens for study, which Lesquereux identified and labeled *Sph. filiculme*. Some of these specimens are from the type locality, but they agree with *Sph. oblongifolium* in leaf shape, size, and arrangement. Other specimens in the collection, also labeled *Sph. filiculme* by Lesquereux, do not conform with *Sph. oblongifolium;* however they approach the latter to such a degree that they might be considered a variety. The most important digression from *Sph. oblongifolium* occurs in the shape of the leaves. Specifically, the sides of the leaves are more nearly straight, and the leaves are widest near the distal margin. This contrasts with *Sph. oblongifolium,* in which the lateral margins of the leaves are conspicuously convex, and the leaves are widest in the middle.

Since there is a variation in the leaves of the various specimens in the Harvard Biological Laboratories collection, all of which Lesquereux identified and labeled *Sph. filiculme,* and since the type is not available for study, it is impossible to determine whether the species should be placed unconditionally in *Sph. oblongifolium* or in a variety of the latter.

2. **Sphenophyllum latifolium** Wood

Sphenophyllum latifolium Wood, 1866, American Phil. Soc., Trans., 13:347, pl. 8, fig. 3.

Lesquereux (1880, p. 53) and Jongmans (1936) considered *Sph. latifolium* synonymous with *Sph. longifolium.* The type has not been available for study and is probably lost, but small fragmentary isolated leaf whorls at the U. S. National Museum labeled *Sph. latifolium* (apparently determined by D. White) do not belong to *Sph. longifolium,* as both the distal margin and the venation are quite different. However, in the absence of the type of *Sph. latifolium* Wood, it is impossible to state that the specimens in the Museum labeled *Sph. latifolium* are the same as the type.

3. **Sphenophyllum vetustum** Newberry

Sphenophyllum vetustum Newberry, 1889, Cincinnati Soc. Nat. Hist., Jour., 12:55, pl. 6, fig. 1.

A study of the type specimen, kindly loaned by Dr. Wells, Geology Department of Cornell University, and now in the U. S. National Museum, shows that it does not belong to the Articulateae. The figure in Newberry (1889, pl. 6, fig. 1) shows all of the details observable on the type. The organic fragments of leaves, which are incompletely preserved on limestone, indicate from the leaf arrangement that the plant is a fern or pteridosperm and not a species of *Sphenophyllum.*

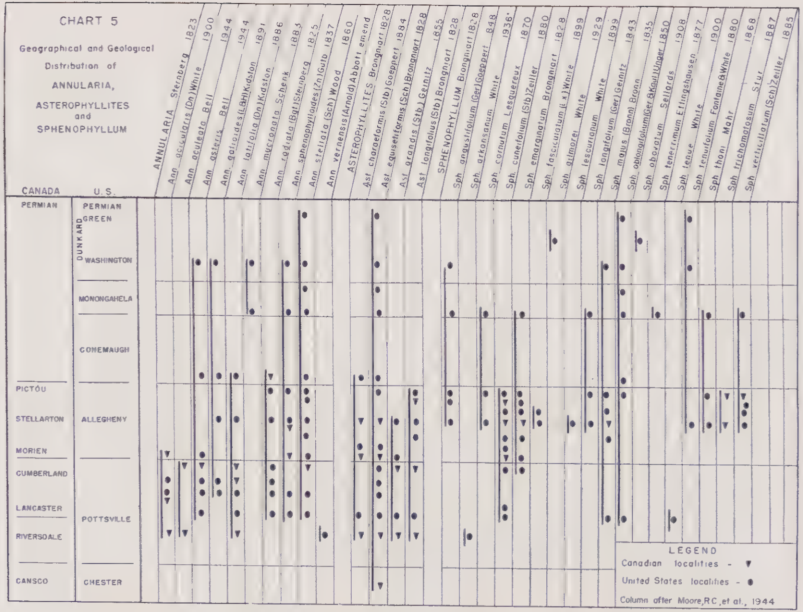


Chart 5. Geographical and Geological Distribution of *Asterophyllites, Annularia, Sphenophyllum.*

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PLATES

The cost of the engraving of the plates has been met by the Faber Fund for Paleontologic Research at the University of Cincinnati Museum, research fund from the Graduate School of Arts and Science of the University of Cincinnati, and the author.

Explanation of Plate 35*

* Figures 1-45, unless otherwise stated, are all Promar projection tracings of transfers or camera lucida tracings of slides derived from transfers. Figures 46-81 are photographs of specimens on shale, transfers or slides. They are deposited at CINC unless otherwise stated in each figure.

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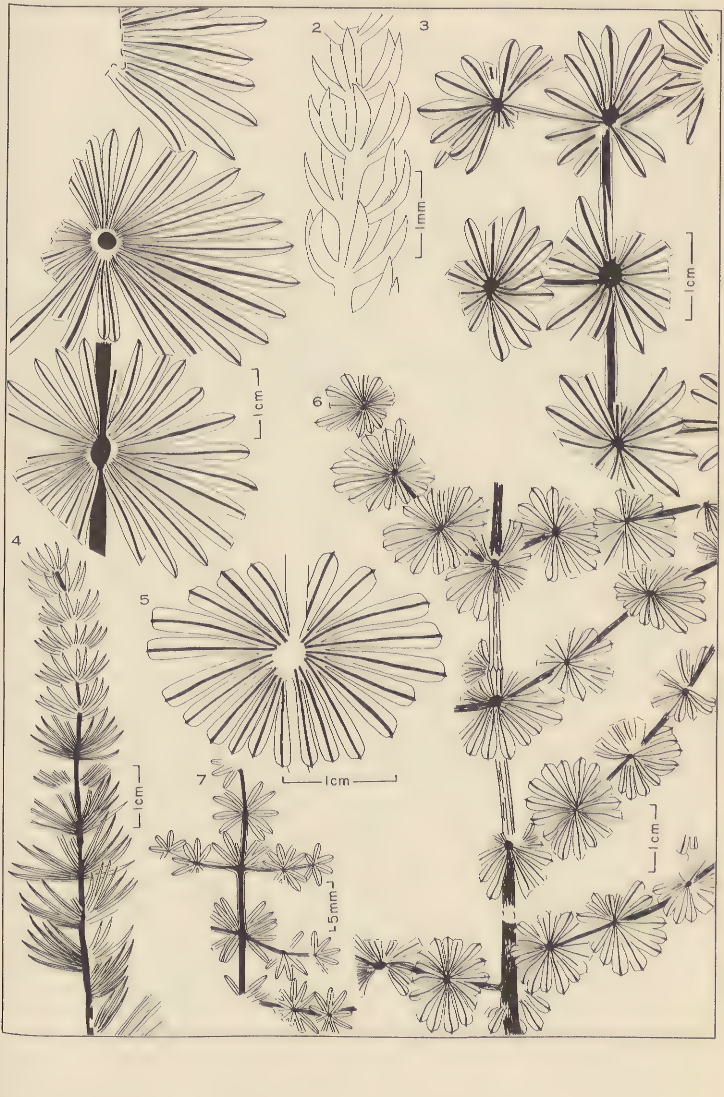
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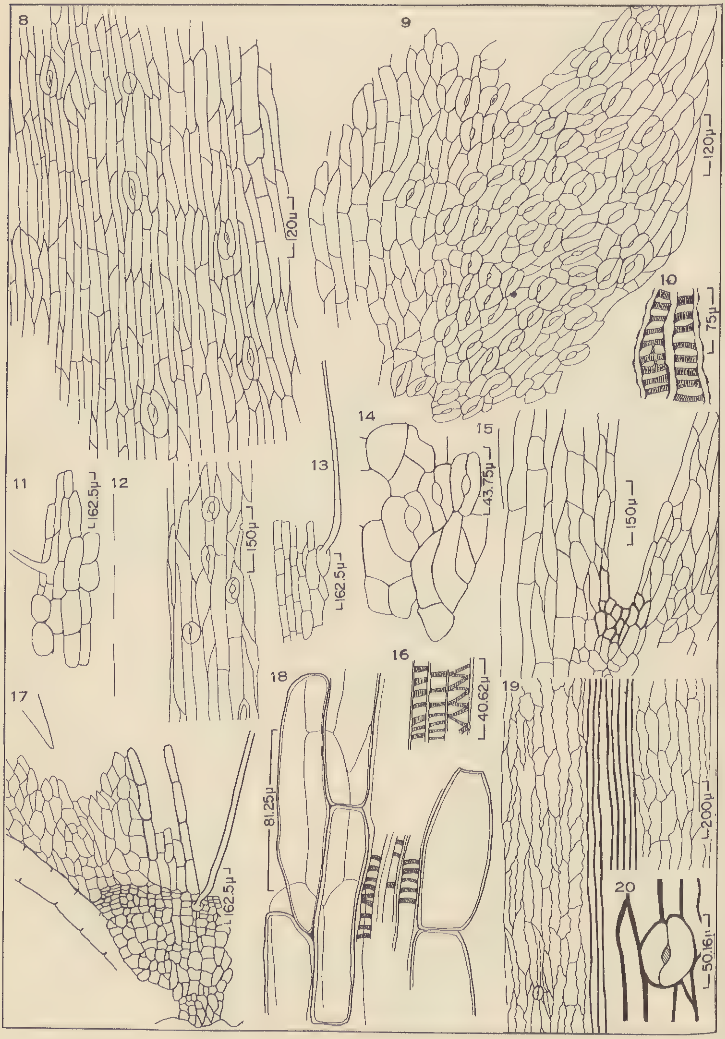
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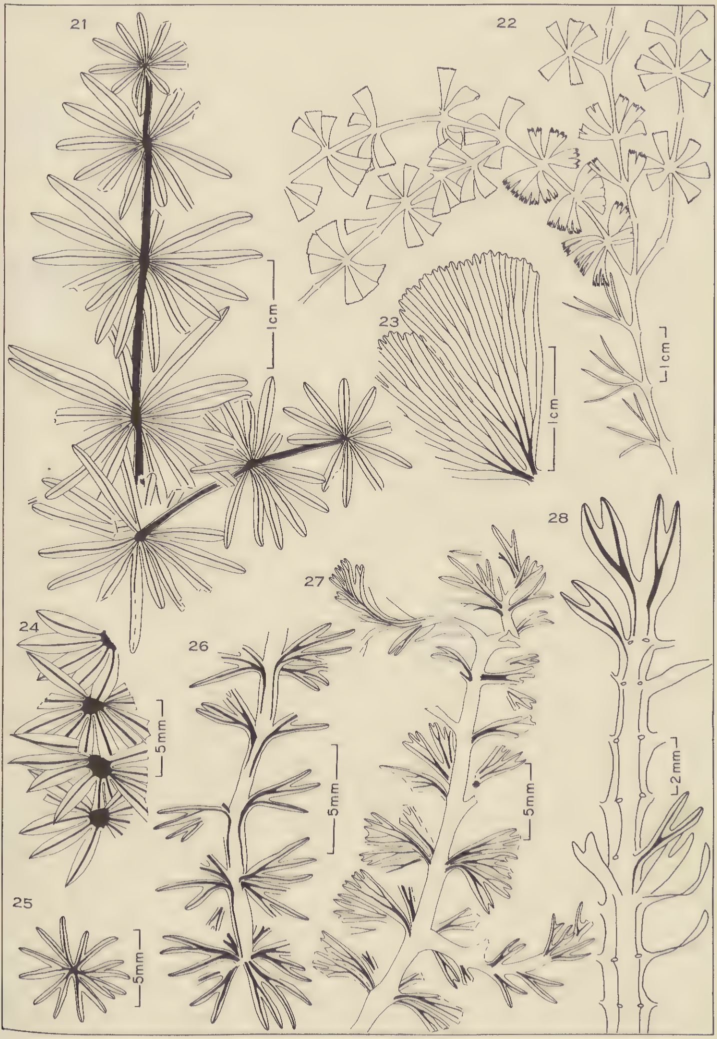
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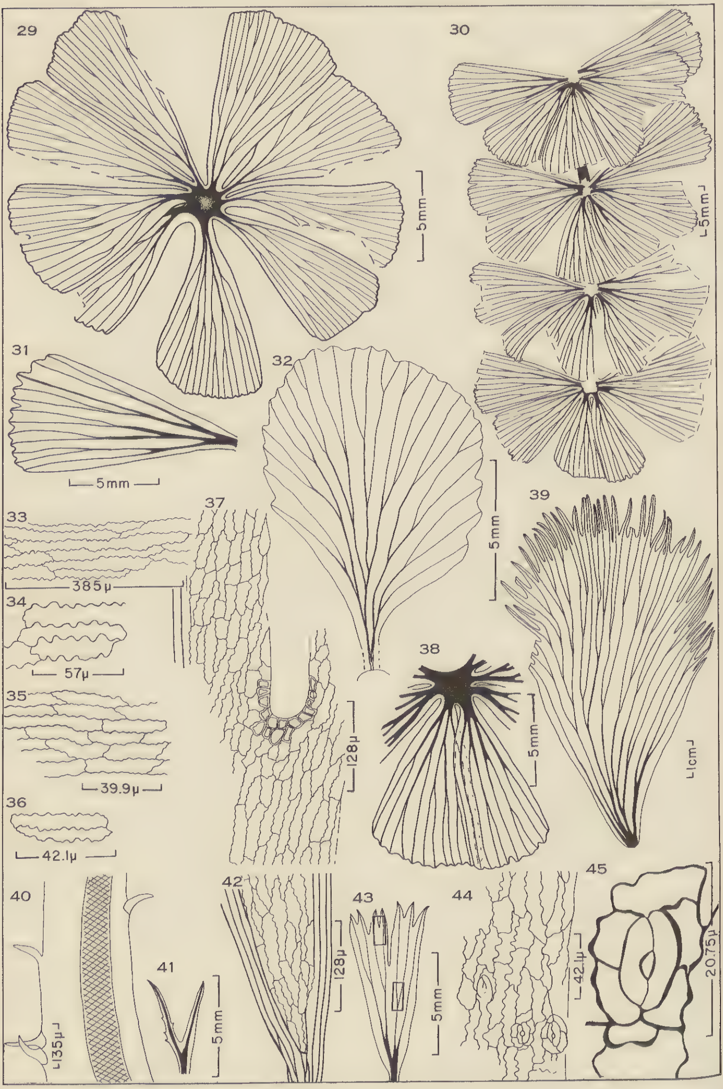
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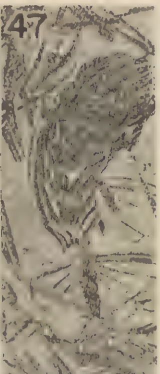
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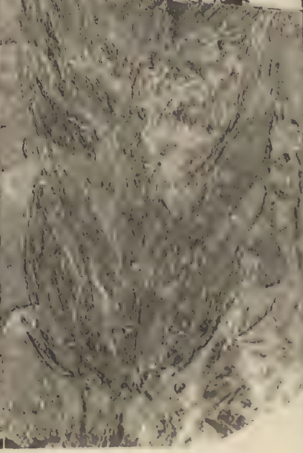
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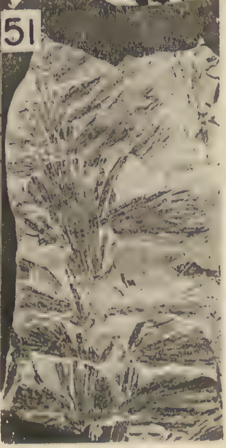
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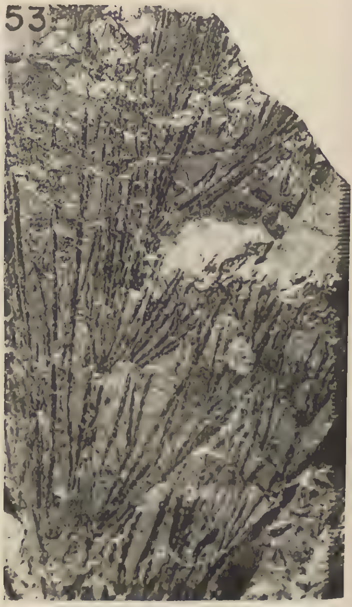

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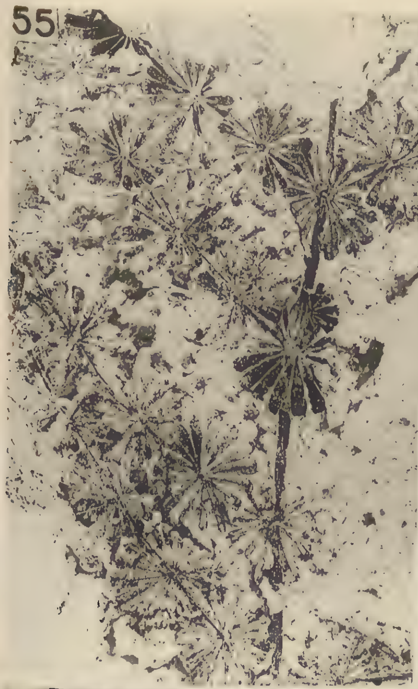
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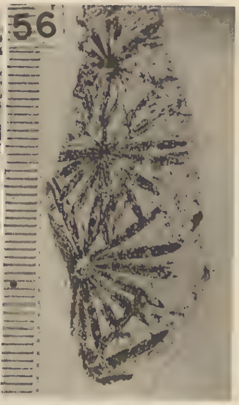
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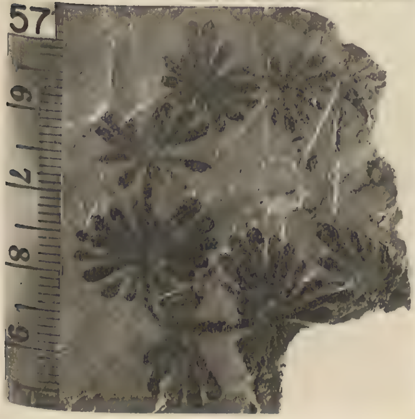
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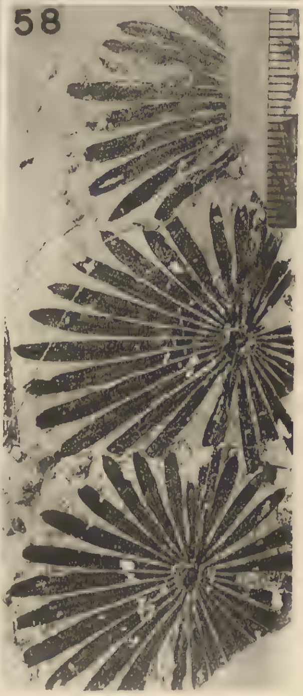
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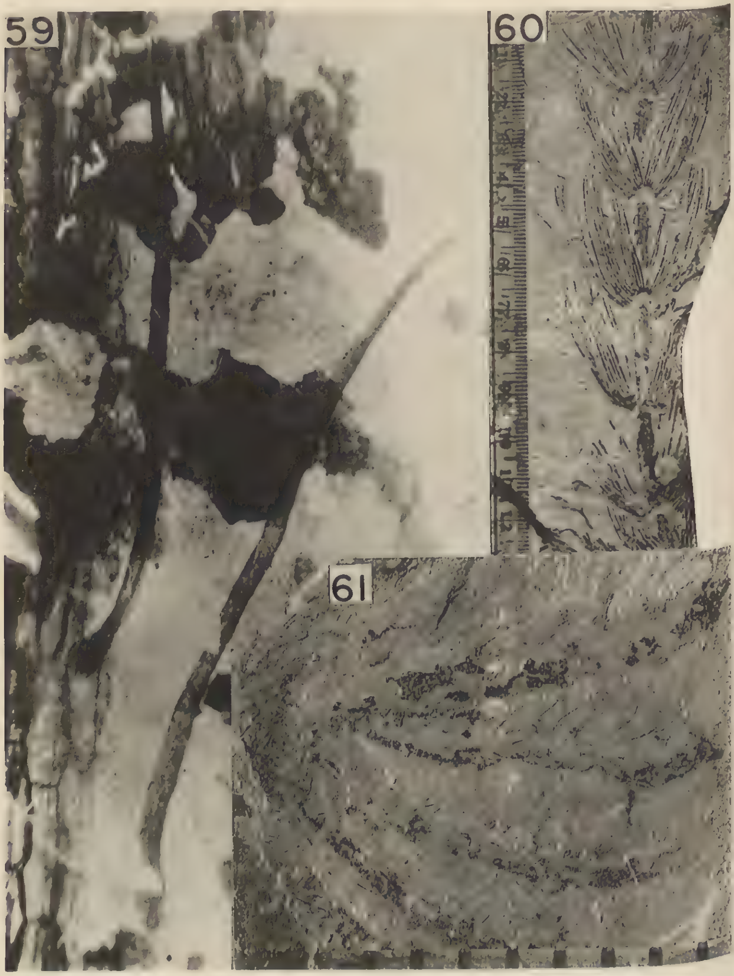
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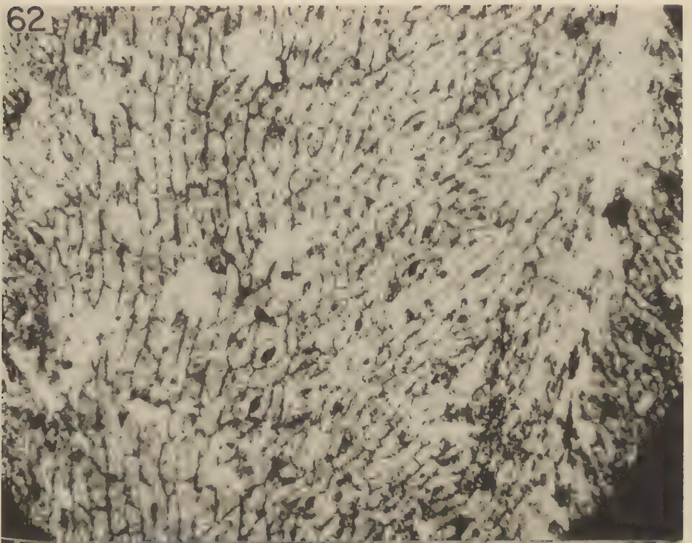
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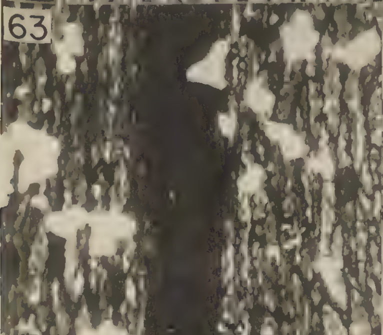
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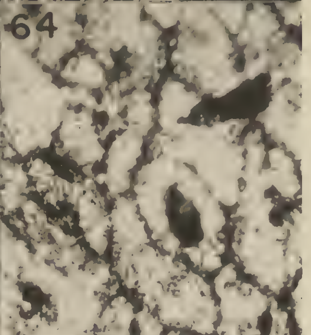
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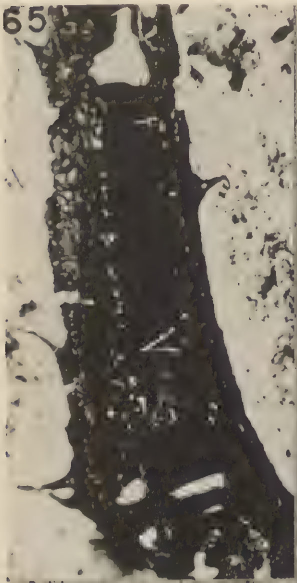

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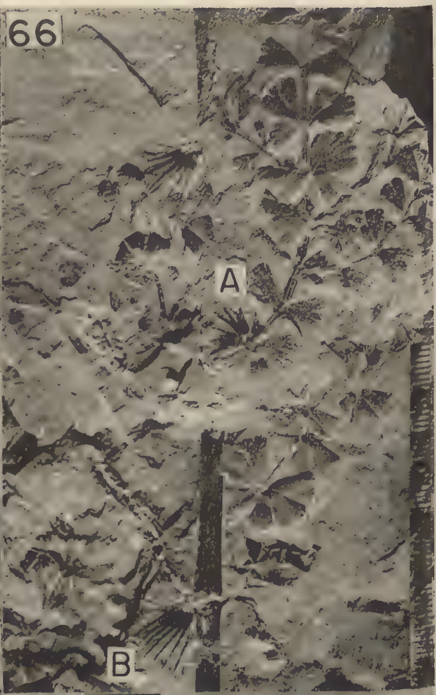

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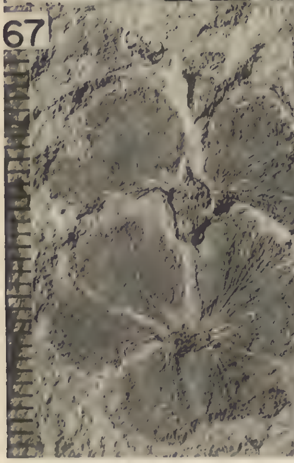

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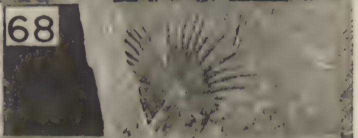

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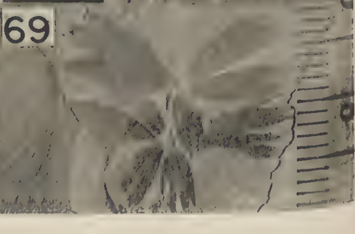

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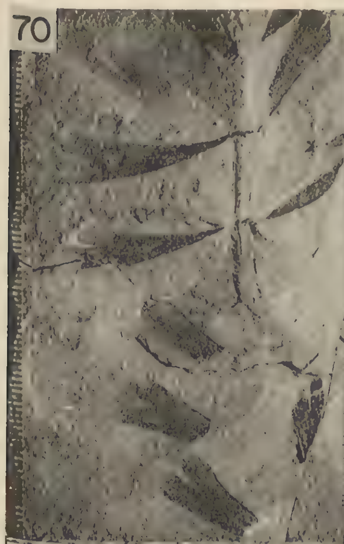
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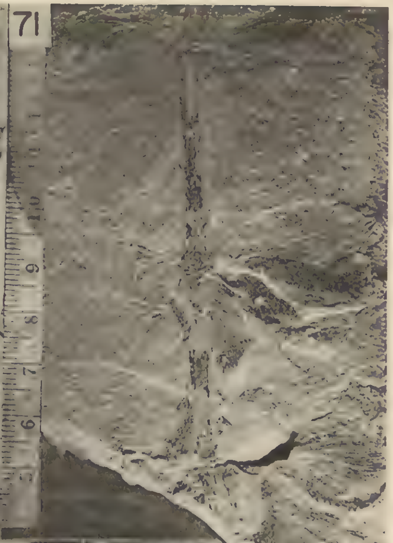
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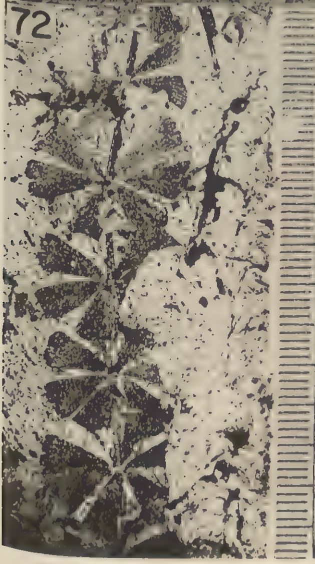
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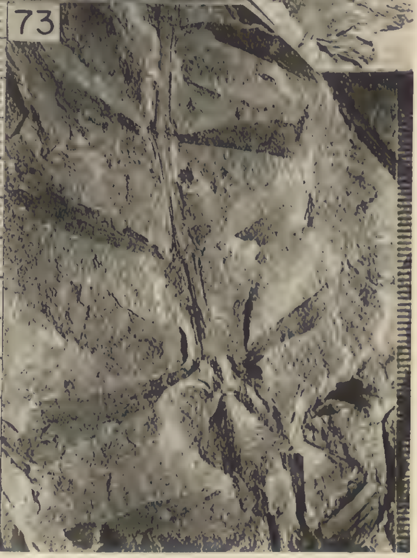
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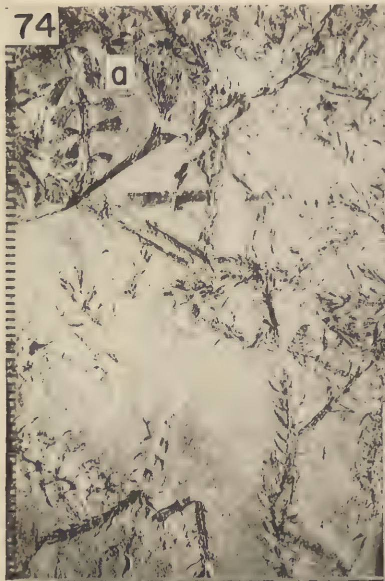

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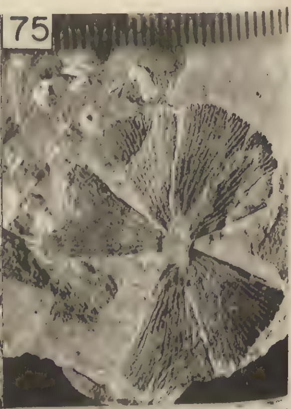

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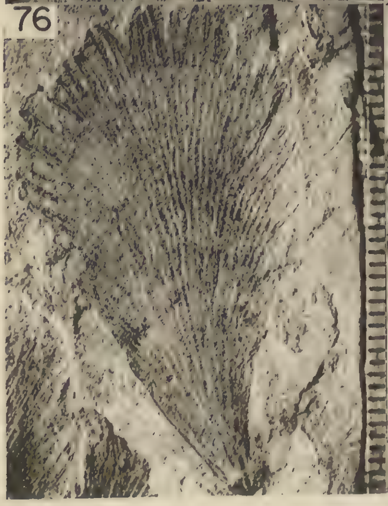

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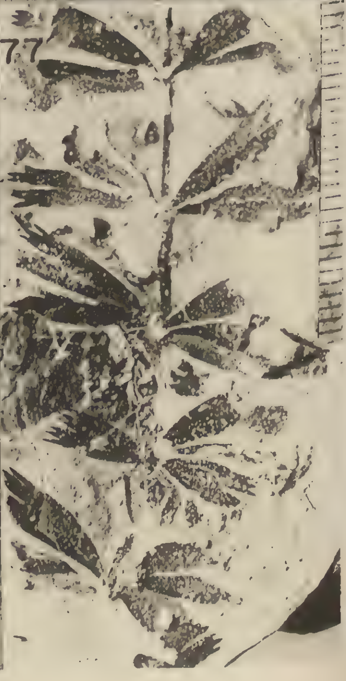

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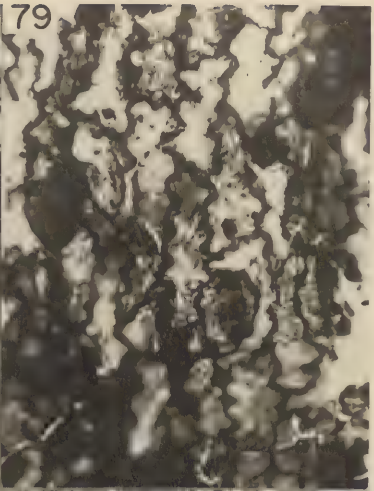

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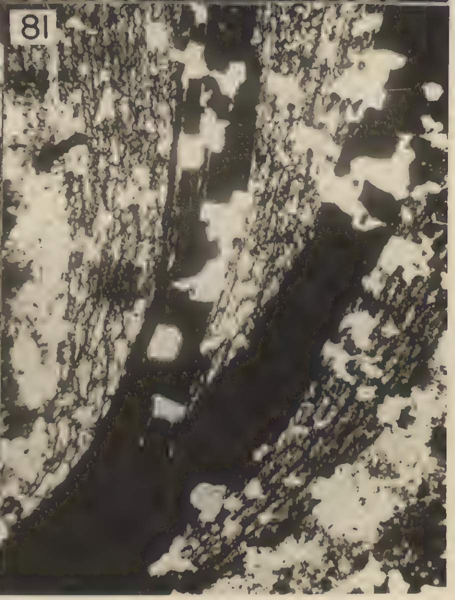

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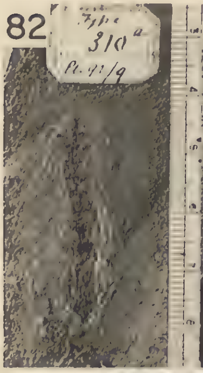
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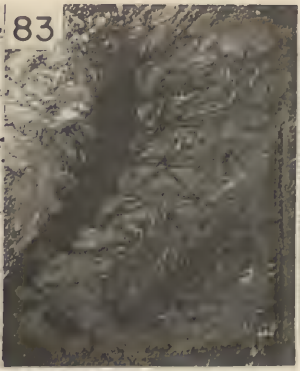

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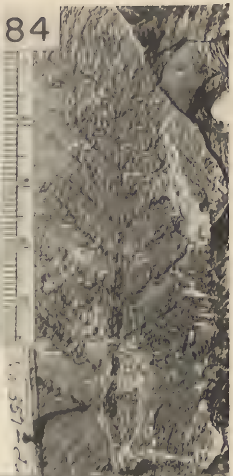

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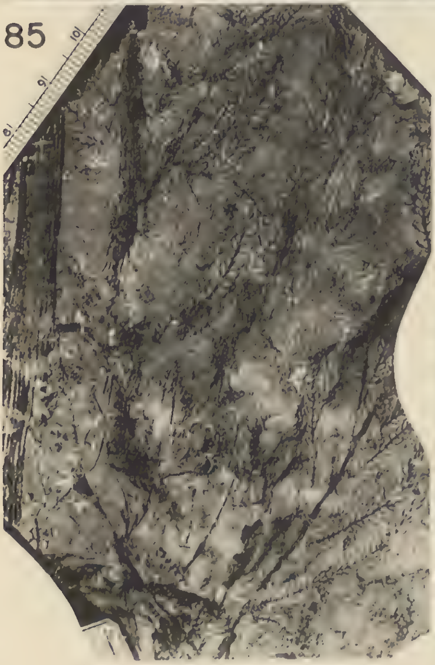

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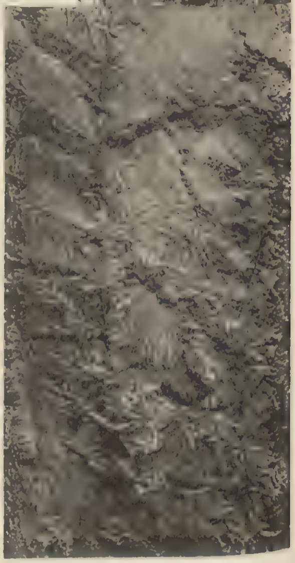

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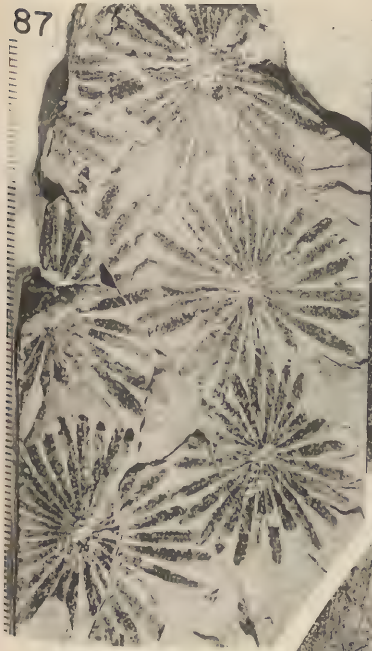

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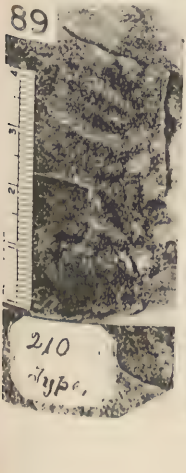
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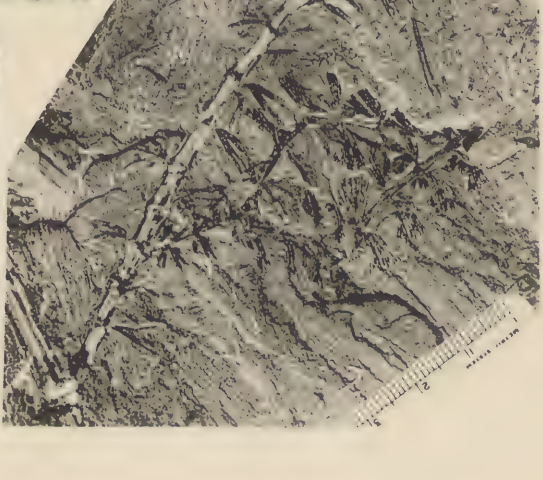

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THE GEOLOGY OF CARRIACOU

By

P. H. Martin-Kaye

Government Geologist, Windward Islands

October 15, 1958

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THE GEOLOGY OF CARRIACOU

P. H. Martin-Kaye
Government Geologist, Windward Islands

ABSTRACT

The Lesser Antillean Grenadine Island of Carriacou is described particularly in relation to recent paleontological evidence. The succession is largely of andesitic and variably agglomeratic and stratified tuffs with some limestones for the most part of upper Eocene, upper Oligocene, and lower Miocene age with some younger horizons. Andesitic to basaltic flows and dikes occur. A geological map of the island is given.

INTRODUCTION

GENERAL DESCRIPTION

Carriacou is the largest of the Grenadine islands which lie between St. Vincent and Grenada in the southern Lesser Antilles. It may be visited by means of the mail schooner service from Grenada from which it is administered. The chief settlement is Hillsborough, situated on a fine bay on the western side, but the population of about 8,000 is well dispersed throughout the island. There is an ample system of roads and tracks and more or less every part is readily accessible.

The shape of the island can be seen in the accompanying map. It is some 7½ miles between furthermost extremities and is mostly a little less than two miles wide. An axial range of hills approaches 1,000 ft. in its two highest summits, Chapeau Carre and High North, and in its central section is in escarpment form with dip slope to the east. Relatively sizeable coastal flats terminate some of the lower slopes particularly in the Hillsborough vicinity, and these commonly possess splendid sandy beaches. Elsewhere as at Kendeace, Cistern, and S. W. Points the coastline is cliffed and rugged.

GENERAL GEOLOGY

Geologically the island is of particular interest because of the evidence that it supplies on the history of the Grenadines and the southern end of the Lesser Antillean arc. It has been briefly discussed by Harrison (1896), at greater length by Earle (1924), and in excellent accounts in some detail by Lehner, and elsewhere by Trechmann (1935). Some further brief description seems called for, however, on account of the work kindly undertaken on the Foraminifera by Professor W. Storrs Cole of Cornell University who has recently published his conclusions (Cole, 1958), and by Dr. H. Bolli of the Trinidad Oil Company who also re-examined some of Lehner's material. Moreover of the published works which give an account of the general geology only Trechmann's can be rated as generally accessible and this, whilst outlining the stratigraphy and describing and figuring many of the megafossils, contains only an outline sketch map of the island. The present fieldwork and map is far from complete, however, and more work is certainly desirable.

In brief Carriacou's geology consists of a series of calcareous tuffs and limestones overlying a usually stratified and commonly tuffaceous series of volcanics, all being fossiliferous, at least in part, and ranging in age from Upper Eocene to Miocene. Andesitic to basaltic flows and sills range through the succession which has been folded and which is patchily and unconformably overlain by ? Pliocene and more recent superficial deposits. Lehner adopted a threefold subdivision for the main sequence: The Upper Tuffs Series and the Lower Tuffs Series, separated by the Carriacou limestone series. This convenient arrangement was followed by Trechmann and is used again here, although not as originally defined.

The most prominent and readily mappable structure is a NE-SW elongated basin in the East but showing only in part, the remainder being cut off by the coast. Overall the dips are mainly to the S.E. at moderate angles although strikes in many directions are encountered. The stratigraphy is tabulated below:

STRATIGRAPHY OF CARRIACOU

Recent		Beach sands, alluvium, valley fill
Pliocene or Upper Miocene	Upper Tuffs	Tarlton Point beds and Point St. Helene beds (Pt. St. Hilaire)
		Unconformity
Lower Miocene		Grand Bay beds with *Globorotalia fohsi fohsi* Upper limestones
		? Unconformity
	Carriacou Limestone Series	Mt. Royal beds Carriacou limestone Calcareous tuffs (of Lehner) with *Globigerinatella insueta* Belmont beds with *Catapsydrax stainforthi* Limestone lenses
		? Unconformity
Upper Oligocene	Lower Tuffs	Tuffs, agglomerates with fossiliferous limestone lenses.
		? Unconformity
Upper Eocene		Hillsborough Rectory limestone

LOWER TUFFS

The oldest rocks occur in the western part of the island and consist mainly of agglomeratic tuffs of andesitic character. They are often bedded, sometimes calcareous, and occasionally develop limestone lenses. The series includes both upper Eocene and Oligocene rocks which will ultimately need to be differentiated by further mapwork.

Upper Eocene has been established so far in only one locality in the Hillsborough Rectory limestone, north of Hillsborough and outcropping on the Hillsborough-Craigston road as a hard, blocky, buff to brown limestone, in part crowded with larger Foraminifera and elsewhere containing some rather fragmented molluscan remains. Professor W. Storrs Cole (Cole, 1958, p. 220) noted amongst the Foraminifera abundant specimens of *Lepidocyclina* (*Pliolepidina*) *pustulosa tobleri* H. Douvillé, rarer specimens of *Lepidocyclina* (*Pliolepidina*) *pustulosa* H. Douvillé, and *Lepidocyclina* (*Pliolepidina*) *macdonaldi*; and a few fragments of *Asterocyclina minima* (Cushman) in all suggesting an upper Eocene age.

Lehner mentioned other orbitoidal limestones as occurring in the northwest part of the island at the cliff west of Anse la Roche Estate house and at the southwest end of Petit Carenage cliff, but unfortunately I have not examined these. They may be the same age as the Hillsborough limestones as Lehner evidently supposed, although he regarded them all as probably Oligocene. Oligocene limestone lenses do occur at various points in the northern part of the island. North of Windward Village thin rather hard white algal limestones with scattered larger Foraminifera outcrop at the shore and dip southward. A hard semisilicified splintery foraminiferal limestone occurs in blocks below Meldrum, and other loose blocks may be found by the Anse la Roche road and also near the road between Bogles and Belvidere. Doubtless there are more occurrences elsewhere. More to the south, a lens crossed by the Brunswick road may also be of the same age. Professor Storrs Cole's composite list for the foraminiferal assemblages of the Windward, Meldrum and Bogles—Anse la Roche limestones (Cole, 1958, p. 221) is *Lepidocyclina* (*Nephrolepidina*) *vaughani* Cushman, *L.* (*N.*) *tournoueri* Lemoine and R. Douvillé, *L.* (*Lepidocyclina*) *waylandvaughani* Cole, *L.* (*L.*) *canellei* Lemoine and R. Douvillé, *L.* (*L.*) *giraudi* R. Douvillé, *Heterostegina antillea* Cushman, *Miogypsina* (*Miolepidocyclina*) *panamensis* (Cushman), and *M.* (*Miogypsina*) *antillea* (Cushman). The stratigraphic determination is upper Oligocene, equivalent to part of the Caimito formation of Panama.

In addition to these harder limestones some of the ashes are foraminiferal. One of Lehner's samples recently re-examined by Dr. H. Bolli showed a rich assemblage of mainly calcareous Foraminifera including *Globigerina* cf. *venezuelana, Globorotalia opima opima,* and *Catapsydrax dissimilis*, suggesting the *Globorotalia opima opima* zone of Trinidad's Oligocene. Unfortunately the precise localities of Lehner's samples cannot now be ascertained.

The limestones only occupy a small proportion of the succession which is mainly composed of agglomeratic tuffs calling for no particular comment. Exposures are good in coast sections north of Hillsborough to Petite Carenage, and in the SW peninsula. A fairly frequently encountered type contains blocks of pink and grey andesite speckled with numerous rather lathlike felspars this being a common rock throughout the Lesser Antilles but particularly noticeable in St. Kitts and Nevis. At Cistern Point well-bedded purplish and brown calcareous volcanic sands are found.

In the promontory to the southern side of Tyrrel Bay, blocks of coarse-grained basic rocks are clustered in some of the agglomerates. These are of gabbro and eucrite and are similarly found on Mabouya island which lies about half a mile north of Cistern Point. Rocks of this description are found under like circumstances or as occasional stream or beach pebbles in many of the West Indian islands and are also common amongst the material erupted in 1902 by Soufriere volcano in St. Vincent.

THE CARRIACOU LIMESTONE SERIES

The Oligocene and older Lower Tuffs pass upwards into the Miocene Carriacou limestone series as they become increasingly calcareous. The Miocene boundary occurs some way below the main limestones, but for the most part its precise position remains to be established. It may be, however, that there is some unconformity between the Oligocene and Miocene of Carriacou, local folding and erosion being recorded for this period in Trinidad. Certainly some of the lower horizons of the Miocene here are pebbly and amongst the pebbles of conglomeratic layers at Belmont are some of a green limestone similar to those mentioned by Lehner as found on Bogles beach. Greenish limestones, presumably Oligocene but perhaps older, do outcrop near Bogles and probably form the source of the beach pebbles.

The main outcrops of the Carriacou limestone series are found between Pt. St. Hilaire and Kendeace Pt. by way of the Top Hill Ridge. The structure in the vicinity of Limlair, Meldrum, and Dover, and northwards to Windward is complicated by faulting and amphisteginal limestones such as form the most prominent member of the series outcrop again near Windward Village. Miocene rocks also extend as far as Belmont towards the south of the island.

The Belmont beds are apparently basal Miocene and consist of a series of ashy rocks, in various parts marly, sandy, clayey, and sometimes pebbly. In the low cliff sections south of the point where the road from Harvey Vale reaches the coast brown, variably clayey, and calcareous, part agglomeratic, part conglomeratic ashy sandstones are at least locally fossiliferous. This seems to have been a previously unnoticed megafossil locality, lamellibranchs being fairly common but were not collected. Dr. Bolli encountered fairly rich and predominately planktonic foraminiferal fauna in a sample from Belmont sea cliff. He records *Globorotalia mayeri* (coiling at random in either direction), *Globigerinoides triloba* group, *Globoquadrina altispira* group, ? *Globorotalia fohsi barisanensis, Globigerina venezuelana, Catapsydrax unicavus* and *Catapsydrax stainforthi* (scarce). This assemblage belongs either to the *Catapsydrax dissimilis* zone or *Catapsydrax stainforthi* zone of the Trinidad Cipero formation and which are regarded as lowermost Miocene. Lehner's samples also include material from *C. dissimilis* zone *s. l.* The exact locality is not known, however, although he described from the general vicinity of Belvidere a richly fossiliferous bed containing numerous pteropods, other Mollusca, some echinoids and fish teeth, tentatively determined as Miocene by H. Nageli whilst a close-by orbitoidal marl was taken as Oligocene. This megafossiliferous bed may well correlate with those at Belmont.

In terms of Trinidad Cipero formation zonation there is a gap between the Belmont beds and the next zone assemblage positively determined in the recent sampling. However Lehner's material includes assemblages of the *Globigerinatella insueta* zone. A sample collected on the Top Hill Road from the marls below the Carriacou limestone was questionably placed in the stratigraphically higher *Globorotalia fohsi fohsi* zone. Confirmation of this is needed since the Grand Bay beds overlying the Carriacou limestone series are indisputably in this zone.

The Carriacou limestone outcrops on the crest of the Belair-Mt. D'Or ridge, down to Bretache Bay and thence to Kendeace. Included are various flaggy or more blocky limestones, white to buff or yellow in colour and generally not notably megafossiliferous but characteristically crowded with Foraminifera. These include abundant *Amphistegina* sp., *Operculinoides cojimarensis* (D. K. Palmer), and rare *Miogypsina* (*Miolepidocyclina*) *staufferi* Koch. Professor Cole places the assemblages as Miocene and correlating roughly with the Cojimar formation of Cuba, the Tuxpan formation of Mexico, and the Brasso clay formation of Trinidad. Lehner on grounds of the lithology and position of the Carriacou limestone had earlier suggested a correlation with the Tamana-Guaracara limestones of the lower Miocene of Trinidad's Central Range.

Kendeace Point provides excellent exposures. The upper beds as shown in the cliffs near the shore on the northern side consist of rather sandy limestones and marls, fairly well-bedded and in part even flaggy. They apparently belong to the upper limestones and not to the Carriacou limestone series. Here some faulting is shown and angular unconformity between stratified limestones is also to be seen at one point. The junction between upper limestones and the Carriacou limestone series may belong here. A small basalt dolerite intrusion is found nearby. Seawards, bedded limestones continue, sometimes with shell fragments or algal nodules and with some pebbly horizons. Towards the tip of the promontory the Carriacou limestone proper is encountered, this being fine grained and carrying scattered echinoids. At the point the Carriacou limestone passes downwards into well-stratified sandy and clayey beds, some of which are crowded with molluscs. Occasional terebratulids may be found. At the base the series becomes conglomeratic. These latter rocks are stratigraphically below the Carriacou limestone proper although conformable with it, and on his map Lehner put them in the Lower Tuff series. They are presumably Miocene and may possibly be as old as the Belmont beds.

On the north coast of Pt. St. Hilaire (Or Helene) cross-bedded calcarenites and some pebbly horizons alternate with amphisteginal limestones. One more marly horizon gave a smaller foraminiferal assemblage that Dr. H. Bolli regards as questionably referable to the *Globigerinatella insueta* zone of Trinidad. As indicated on the map this and the adjacent areas around Limlair, Meldrum, and towards Belair need elucidation.

Conglomerates tentatively termed the Mt. Royal beds overlie the main amphisteginal layers and apparently run from Belair to Bretache and whilst mostly suggested only by surface strewn blocks are to be well seen at Mt. Royal and fairly well in the roadside between Bretache and Grand Bay behind Kendeace. In the actual promontory at Kendeace they may be represented by some of the pebble hands. This horizon is probably Dr. Trechmann's volcanic agglomerate member noted as carrying a *Pleurotoma* fauna and lying below his Grand Bay beds. He placed the thickness at 30 ft.

UPPER TUFFS

Apart from superficial deposits and a young limestone near Craigston the youngest rocks in Carriacou are found in the axis of the basin-structure and are well exposed in the Grand Bay area and at various parts of the coast between Kendeace and Pt. St. Hilaire. The Mt. Royal beds are succeeded upwards by white, in part rather flaggy, somewhat pulverent limestones containing scattered grains of ferromagnesian and other minerals and which are tentatively termed the Upper Limestones. These cap the higher hillside spurs above Grand Bay and Mount Pleasant. Despite their mappable extent they are probably less than 50 ft. thick. I have no fossils from them, but they are probably better placed with the Upper Tuffs of Lehner and Trechmann's Grand Bay beds than with the Carriacou limestone.

The Grand Bay beds are rather variable ashy rocks, often highly fossiliferous. Trechmann placed them as lower Miocene (? Burdigalian) and equivalent to the Cercado or Baitoa beds of the Dominican Republic. They frequently carry a good predominantly planktonic foraminiferal fauna of the *Globorotalia fohsi fohsi* zone of Trinidad's Cipero formation. Amongst the assemblage Dr. Bolli records *Globorotalia fohsi fohsi, G. praemenardii, G. mayeri, G. obesa, Globigerinoides triloba* group, *G. rubra G. obliqua, Globoquadrina altispira altispira, Sphaeroidinella grimsdalei*, and *Globigerina venezuelana.* Lithologically they are composed of rather irregularly stratified, earthy-looking brownish clayey or sandy marls and limestones alternating with more shaley layers. Parts are pebbly. They are usually but not always calcareous. Molluscs are sometimes common and have been described and figured by Trechmann. Plant remains also occur. The beds seem to be 50 or 100 feet thick.

LOWER PLIOCENE OR UPPER MIOCENE

Trechmann referred a megafossil assemblage derived from the higher tuffs of Pt. St. Hilaire (St. Helene) and Tarlton Point to the lower Pliocene (or Plaisancian) noting it as containing a curious mixture of land

and marine forms. Lehner considered all the Upper Tuffs to be questionably upper Miocene. Some further mapping is required since I did not separate these later beds satisfactorily and yet collected a sample yielding a *Globorotalia fohsi fohsi* fauna from Tarlton Point, although possibly reworked.

SUPERFICIAL DEPOSITS

Superficial deposits are extensive, particularly in the neighbourhood of Hillsborough and Harvey Vale. They are poorly exposed but do not seem to call for particular comment except for the beds exposed in the sea cliffs towards Bretache below Dumfries. Here low cliffs gradually increasing in height northwards expose relatively incoherent generally brown clayey sands with marly beds, or with layers of algal nodules and pebbly bouldery horizons containing both volcanic and limestone blocks. They are tolerably well stratified with a low dip seaward. Some black sand layers suggest beach deposition and the general appearence is that of a late formation. Nearby, however, numerous basalt blocks scatter the surface of a rather conglomeratic somewhat calcareous volcanic sandstone series which is likely to be pre-Carriacou limestone.

IGNEOUS ROCKS

The igneous rocks of Carriacou are mainly of basalt and basic andesites. At Mount Royal scattered boulders of olivine basalt are strewn about the hillside and carry much olivine and pyroxene as often somewhat irregularly shaped phenocrysts up to 1.5 mm. in a murky groundmass. The boulders scattered on Tarlton Point are also basalt, olivine forming the main phenocrysts which are, however, smaller and less numerous than at Mount Royal. Granules of pyroxene and flow oriented laths of bytownite form the groundmass.

Approaching Cistern Point on the south side there is a dark-coloured rock with abundant 3-4 mm. ferromagnesian phenocrysts. It seems to be a somewhat more basic variety than usual of the augite andesite with the prominent augite phenocrysts which is so noticeable at points in the islands from St. Vincent southwards and particularly in Grenada. It seems debatable whether it should be termed an andesite or a basalt as a general type. Here the large augites are set amongst small phenocrysts of labradorite and fairly frequent but relatively subsidiary olivine, the base being of pyroxene granules and feldspar.

Between Harvey Vale and Belmont and also about 1/3 mile north of Bogles by the Anse la Roche road are fine-grained dark rocks composed largely of feldspar but with widely scattered euhedral augite phenocrysts and a little pyroxene in the base. Plagioclase phenocrysts about labradorite, fresh in appearence and displaying a moderate degree of normal zoning, occupy about 20% of the slide.

On the western coast in the Hermitage region the cliffs display a section of nearly horizontal, slightly calcareous rather roughly bedded volcanic sandstones overlain by a flow about 25 ft. in thickness. The underlying sandstones are cut by dikes of similar composition to the flow. The flow is of a pyroxene basalt with numerous labradorite phenocrysts and large green augites, the phenocrysts in all occupying about 50% of the slide. Numerous vesicles containing zeolites occur. The groundmass is heavily dusted with opaque grains.

Basalts also occur on the western side of the point between Belmont and Bretache Bays, in a small exposure and cutting the limestones on the north side of Kendeace Pt. and at Belair, and elsewhere.

Andesites are less common except in the pyroclastics. They are generally mid to pale grey rocks with normally or oscillatorily zoned plagioclases about andesine-labradorite. Quartz is inconspicuous. Augite and sometimes orthopyroxene form further phenocrysts, sometimes of large size. These rocks occur in the promontory between Gt. and Lt. Bretache Bay, as blocks at Belmont, in the Hermitage area and doubtless elsewhere.

A hornblende andesite is found on Chapeau Carre, the hornblendes with a pronounced corona largely of opaque dust, but basalts also occur here.

Dikes occur at Hermitage Pt., St. Hilaire, and near Craigston striking at 125°, 150° and 083° respectively.

CONCLUSION

The Carriacou region has thus been the site of recurrent volcanic activity at least since the upper Eocene, relative quiescence in part of the upper Eocene, upper Oligocene and lower Miocene favouring the development of reefal and lagoonal conditions at these times. The upper Oligocene reefal limestone faunas suggest correlation with part of the Caimito formation of Panama whilst the *Globorotalia opima opima, Catapsydrax* *dissimilis* or *C. stainforthi, Globigerinatella insueta*, and *Globorotalia fohsi fohsi* zones of the Trinidad upper Oligocene and lower Miocene are represented by assemblages from more marly layers. The *Globorotalia fohsi fohsi* beds (Grand Bay beds) have been correlated with the lower Miocene Baitoa formation of the Dominican Republic. Further fossiliferous beds have been placed as lower Pliocene or upper Miocene. These latter have been cut by dike rocks but the Grenadine region has not been the scene of any major later Tertiary to Recent volcanic activity such as occurred over much of the remainder of the arc.

There is some suggestion of unconformity between Oligocene and Miocene but decisive evidence is yet wanting. Main deformation was induced by the Plio-Miocene Andean orogeny.

Lehner and Trechmann suggest a larger land mass as indicated by the Plio-Miocene fauna, and it is quite probable that the Grenadines and perhaps Grenada were at one time connected. The other Grenadine islands are largely of volcanics and no similarly fossiliferous succession has yet been recognised in them. The interesting island of Canouan is a further exception possessing a diorite which has metamorphosed a basement sedimentary series, including foraminiferal limestones. The latter were noted by Jukes-Brown in 1893 and compared with the upper Eocene San Fernando beds of Trinidad. Professor Cole's preliminary opinion of recent samples is that they are probably of much the same age as the Carriacou limestone.

Of the neighbouring major islands St. Vincent has no fossiliferous beds so far as is known. Grenada, however, has the rather sharply folded Levera formation which has recently yielded Foraminifera and appears to be upper Eocene in age. Other fossiliferous localities have yielded Oligocene and Miocene assemblages still under study.

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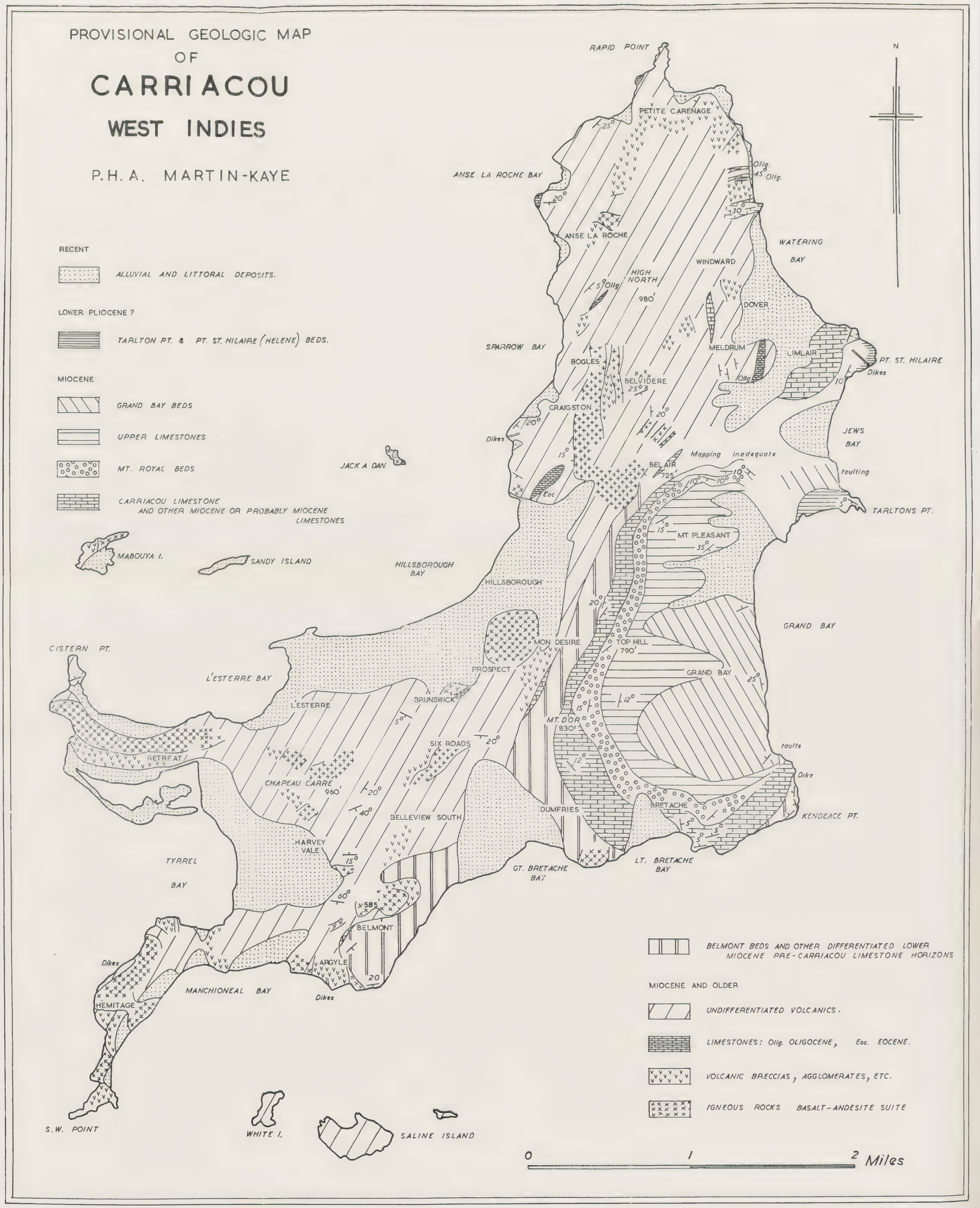
PROVISIONAL GEOLOGIC MAP
OF
CARRIACOU
WEST INDIES
P.H.A. MARTIN-KAYE
RECENT
ALLUVIAL AND LITTORAL DEPOSITS.
LOWER PLIOCENE ?
TARLTON PT. & PT. ST. HILAIRE (HELENE) BEDS.
MIOCENE
GRAND BAY BEDS
UPPER LIMESTONES
MT. ROYAL BEDS
CARRIACOU LIMESTONE AND OTHER MIOCENE OR PROBABLY MIOCENE LIMESTONES
BELMONT BEDS AND OTHER DIFFERENTIATED LOWER MIOCENE PRE-CARRIACOU LIMESTONE HORIZONS
MIOCENE AND OLDER
UNDIFFERENTIATED VOLCANICS.
LIMESTONES: Olig. OLIGOCENE, Eoc. EOCENE.
VOLCANIC BRECCIAS, AGGLOMERATES, ETC.
IGNEOUS ROCKS BASALT-ANDESITE SUITE
N
0
1
2 Miles
RAPID POINT
PETITE CARENAGE
ANSE LA ROCHE BAY
ANSE LA ROCHE
Olig.
45 Olig.
30
25°
20°
WATERING BAY
WINDWARD
HIGH NORTH
980'
5° Olig
DOVER
SPARROW BAY
BOGLES
BELVIDERE
25°
MELDRUM
Olig
LIMLAIR
PT. ST. HILAIRE
Dikes
10
JEWS BAY
CRAIGSTON
20°
Dikes
15
20°
Mapping inadequate
BELAIR
725
faulting
Eoc
JACK A DAN
TARLTONS PT.
10°
10°
10
15°
MT PLEASANT
35°
MABOUYA I.
SANDY ISLAND
HILLSBOROUGH BAY
HILLSBOROUGH
20
GRAND BAY
CISTERN PT.
MON DESIRE
TOP HILL
790'
PROSPECT
L'ESTERRE BAY
GRAND BAY
25°
BRUNSWICK
L'ESTERRE
5°
12°
15
MT. DOR
830'
20°
SIX ROADS
RETREAT
faults
CHAPEAU CARRE
960'
20°
12
Dike
40°
BELLEVIEW SOUTH
DUMFRIES
BRETACHE
KENDEACE PT.
5
5
5
TYRREL BAY
HARVEY VALE
15°
GT. BRETACHE BAY
LT. BRETACHE BAY
60°
x585
BELMONT
Dikes
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20
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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA, PARTICULARLY THE DISCOCYCLINIDS — No. 3

By

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November 15, 1958

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NAMES OF AND VARIATION IN CERTAIN AMERICAN LARGER FORAMINIFERA, PARTICULARLY THE DISCOCYCLINIDS—NO. 3 †

W. Storrs Cole
Cornell University, Ithaca, N. Y.

ABSTRACT

Discocyclinids found in the Orocopia Mountains of southern California are discussed and illustrated. The names of and variation in the two species to which these specimens are assigned are analyzed. In addition, another Californian species, *Pseudophragmina* (*Proporocyclina*) *clarki* (Cushman), is considered. The species of the subgenus *Proporocyclina* are analyzed and keys to the valid species are given.

INTRODUCTION

Recently, during field work in the Orocopia Mountains (Crowell, 1957, p. 1712) of southern California John C. Crowell found beds with abundant discocyclinids at two localities. Specimens were sent to me for identification. Although it was impossible to remove these specimens from the matrix, they were identified readily from random thin sections.

The abundant specimens are *Pseudophragmina* (*Proporocyclina*) *psila* (Woodring). These are accompanied by occasional specimens of *Asterocyclina aster* (Woodring), *Fabiania cubensis* (Cushman and Bermudez) and an *Operculinoides* similar to the one found at the type locality of *P.* (*P.*) *psila* by Woodring (1930, pl. 14, fig. 1) and identified by him as *Operculina* cf. *ocalana* Cushman.

Although the species immediately demonstrated that the fauna was identical with the one described by Woodring (1930) from the south slope of the western Santa Ynez Range, there remained the problem of the relationship, if any, of the species of discocyclinids to similar species elsewhere in the Americas.

In the original description of *P.* (*P.*) *psila* Woodring (1930, p. 151) had written: "*D. psila* is most closely allied to *D. perpusilla* Vaughan found in the Guayabal formation (upper middle Eocene, according to Vaughan) at several localities in the State of Vera Cruz, Mexico. . . . If the Guayabal formation were upper Eocene, *psila* would be regarded as a California race of *perpusilla*." Later, Berthiaume (1938, p. 496) suggested that *P.* (*P.*) *psila* was a subspecies of *P.* (*P.*) *perpusilla.*

Cole and Gravell (1952, p. 725) identified specimens found at Peñon Seep, Matanzas Province, Cuba, with *P.* (*P.*) *psila.* Although numerous discocyclinids were found at Peñon Seep, none of the specimens appeared to be identical with *P.* (*P.*) *perpusilla.*

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As certain specimens in the material from the Orocopia Mountains appeared to resemble *P.* (*P.*) *psila,* whereas others were similar to *P.* (*P.*) *perpusilla,* a study was made not only of these species but also of related species. Recently, Cole (1958 *a*; 1958 *b*) emphasized not only the variation in certain American larger Foraminifera, but also the influence of environment upon the external and internal features of the test. Therefore, it was desirable to evaluate these and related species to ascertain the variation which might occur.

Specimens from the localities which follow were used for this study:

LOCALITIES

CALIFORNIA

Locality 1. Brown limy sandstone layers, two to eighteen inches thick, interbedded in sandstone and siltstone sequence with orange-brown hard sandstone layers containing the most fossils, 2.87 miles south 34° west of Shaver Summit and 1.45 miles north 27° west of Hill 2650, Canyon Spring Quadrangle (Corps of Engineers, U. S. Army, 1944), Riverside County; UCLA loc. 3797.

2. Similar lithology to that at locality 1, 2.75 miles south 35° west of Shaver Summit and 1.52 miles north 23° west of Hill 2650, Canyon Spring Quadrangle, Riverside County; UCLA loc. 3798.

3. Near base of silt member of the Las Llajas formation about 800 feet north and 300 feet west of the southeast corner sec. 30, T 3 N, R 17 W, Santa Susana Quadrangle (USGS, 1951), Chivo Canyon, Ventura County; UCLA loc. 3832.

4. Left side of canyon between Las Llajas and Tapo canyons, a few hundred feet up the main canyon from the mouth of a branch canyon at an abandoned oil well, north side of Simi Valley, Ventura County, collected by W. P. Woodring; sample courtesy of the late T. W. Vaughan.

5. South slope of western Santa Ynez Range, Santa Barbara County, west side of Canada de los Sauces, 1.2 miles above coast (in center of first "O" in Concepcion" on Guadalupe Sheet; Cal. Inst. Tech. loc. 595; specimens available through the courtesy of W. P. Woodring and C. Merriam.

MEXICO

6. Guayabal formation (middle Eocene) type locality, 12 kilometers west of Potrero del Llano, Tampico Embayment area.

FLORIDA

7. Ocala limestone (upper Eocene) on the bank of the Chipola River near Marianna, Jackson County.

TEXAS

8. Moodys Branch marl (upper Eocene), 0.75 mile below Robinson's Ferry on Sabine River, Sabine County.

PERU

9. East of Punta Arenas, Peru, 0.75 mile, at the base of the Talara formation; courtesy of the late T. W. Vaughan.

DISCUSSION OF THE SPECIES OF THE SUBGENUS *PROPOROCYCLINA* VAUGHAN AND COLE

Vaughan in 1945 (p. 114, 115) listed 24 American species referred to the subgenus *Proporocyclina* of which he considered four to be synonyms. Therefore, at that time there were 20 supposedly valid species. Since that time five additional species were described. These are: *P.* (*P.*) *habanensis* Cole and Bermudez (1947, p. 207), *P.* (*P.*) *compacta* Cole and Gravell (1952, p. 720), *P.* (*P.*) *convexicamerata* Cole and Gravell (1952, p. 721), *P.* (*P.*) *penonensis* Cole and Gravell (1952), p. 723), and *P.* (*P.*) *teres* Cole and Gravell (1952, p. 725).

However, the original 20 supposedly valid species listed by Vaughan should be reduced by two as Cole and Gravell (1952, p. 714) transferred *P.* (*P.*) *marginata* (Cushman) to the genus *Discocyclina*, and stated (p. 724) that *P.* (*P.*) *hannai* Cole (1944, p. 84) was a synonym of *P.* (*P.*) *cedarkeysensis* Cole. Thus, there were 23 supposedly valid species retained in the subgenus *Proporocyclina* at the time this study was undertaken.

These 23 species seemingly can be divided into three groups on the appearance of the equatorial chambers. Type I.—Certain species have equatorial chambers which have complete, nearly straight, radial chamber walls, and the chambers are radially elongate (Pl. 50, fig. 1). *P.* (*P.*) *flintensis* characterizes this group. Type II.—A second group, characterized by *P.* (*P.*) *tobleri* (Vaughan, 1945, pl. 37, fig. 4) or *P.* (*P.*) *clarki* (Pl. 52, fig. 10), has equatorial chambers with thin undulatory radial chamber walls, and the equatorial chambers are not radially elongate. Type III.—The final group, typified by *P.* (*P.*) *advena* (Vaughan, 1945, pl. 42, fig. 1), has narrow annuli throughout and more or less imperfect radial chamber walls.

A grouping of the supposedly valid species of *Proporocyclina* follows. To this has been added the year the name was proposed, the type area, and the assigned geologic age.

TYPE I SPECIES

P. (*P.*) *blumenthali* (Gorter and van der Vlerk), 1932	—Venezuela	—Upper Eocene
citrensis (Vaughan), 1928	—Florida	—Upper Eocene
convexicamerata Cole and Gravell, 1952	—Cuba	—Middle Eocene
cushmani (Vaughan), 1929	—Mexico	—Middle Eocene
flintensis (Cushman), 1917	—Georgia	—Upper Eocene
mirandana (Hodson), 1926	—Venezuela	—Upper Eocene
palmerae (Vaughan), 1945	—Cuba	—Upper Eocene
penonensis Cole and Gravell, 1952	—Cuba	—Middle Eocene
perpusilla (Vaughan), 1929	—Mexico	—Middle Eocene
psila (Woodring), 1930	—California	—Middle Eocene
teres Cole and Gravell, 1952	—Cuba	—Middle Eocene

TYPE II SPECIES

P. (*P.*) *clarki* (Cushman), 1917	—California	—Middle Eocene
habanensis Cole and Bermudez,, 1947	—Cuba	—Middle Eocene
peruviana (Cushman), 1922	—Peru	—Middle Eocene
tobleri Vaughan and Cole, 1941	—Trinidad	—Upper Eocene (?)

TYPE III SPECIES

P. (*P.*) *advena* (Cushman), 1921	—Louisiana	—Middle Eocene
cedarkeysensis Cole, 1944	—Florida	—Lower Eocene

cloptoni (Vaughan), 1929	—Lower California	—Middle Eocene
compacta Cole and Gravell, 1952	—Cuba	—Middle Eocene
palenquensis (Vaughan), 1929	—Mexico	—Middle or upper Eocene
perkinsi (Vaughan), 1928	—Jamaica	—Upper Eocene
schomburgki (Vaughan), 1945	—Barbados	—Middle Eocene
zaragosensis (Vaughan), 1929	—Mexico	—Lower Eocene

Cole (1957, p. 35) suggested that in the Type I group *P.* (*P.*) *citrensis* and *P.* (*P.*) *mirandana* were synonyms of *P.* (*P.*) *flintensis*. This suggestion is analyzed fully in the systematic part of this report, and the conclusion is reached that not only are these two species synonyms of *P.* (*P.*) *flintensis*, but also that six other species are synonyms of this species. They are: *P.* (*P.*) *blumenthali, P.* (*P.*) *convexicamerata, P.* (*P.*) *cushmani, P.* (*P.*) *palmerae, P.* (*P.*) *perpusilla* and *P.* (*P.*) *psila*. Thus, the recognizable species in the Type I group are: *P.* (*P.*) *flintensis, P.* (*P.*) *penonensis,* and *P.* (*P.*) *teres*.

The four species of the Type II group are reduced to three as *P.* (*P.*) *peruviana* is considered to be a synonym of *P.* (*P.*) *clarki*. This species is discussed in detail later in this report.

Although the species of the Type III group are not discussed in detail, study of specimens and illustrations demonstrate that the eight species must be reduced to five. It is impossible to separate *P.* (*P.*) *perkinsi* from *P.* (*P.*) *cloptoni* and *P.* (*P.*) *compacta*. The illustrations of *P.* (*P.*) *schomburgki* Vaughan (1945, pl. 16, figs. 1-4*a*) are not adequate. Although there is doubt, this species is similar to *P.* (*P.*) *palenquensis* and has been combined with it. However, more study may prove this to be incorrect.

Thus, there are seemingly 11 readily recognizable species in this subgenus instead of 23. Keys to these species follow. Each statement of the key contains a reference to illustrations which are typical of the characteristic chosen to represent the particular species. Before these keys can be used, the specimens should be classified to type on the characteristics of the equatorial chambers.

KEY TO TYPE I SPECIES

A. Test normally with a large, distinct, dimpled umbo, and a bordering narrow relatively thin rim—*P.* (*P.*) *penonensis* (see: Cole and Gravell, 1952, pl. 103, figs. 3-5).

B. Test umbonate to lenticular .... (see: Pl. 51)

- 1. Floors and roofs of lateral chambers flat—*P.* (*P.*) *teres* Cole and Gravell (see: Cole and Gravell, 1952, pl. 100, figs. 10-12, 14).
- 2. Floors and roofs of lateral chambers arched or curved—*P.* (*P.*) *flintensis* (Cushman) (see: Pl. 51).

KEY TO TYPE II SPECIES

A. Test normally umbonate with a rim—*P.* (*P.*) *clarki* (Cushman) (see: Pl. 52, figs. 3-6, 8, 9).

B. Test normally compressed lenticular—(see: Vaughan, 1945, pl. 37, fig. 5).

- 1. Lateral chambers with thin floors and roofs, numerous (eight to fourteen) in rude tiers—*P.* (*P.*) *habanensis* Cole and Bermudez (see: Cole and Bermudez, 1947, pl. 19, figs. 5-7).
- 2. Lateral chambers with thick floors and roofs, few (eight or less), overlapping—*P.* (*P.*) *tobleri* Vaughan and Cole (see: Vaughan, 1945, pl. 37, fig. 5).

KEY TO TYPE III SPECIES

A. Test normally compressed lenticular—(see: Cole and Gravell, 1952, pl. 100, figs. 4, 5).

- 1. With pronounced pillars—*P.* (*P.*) *zaragosensis* (Vaughan) (see: Vaughan, 1929, pl. 4, fig. 3).
- 2. Without pillars or with small scarcely noticeable pillars—(see: Cole and Gravell, 1952, pl. 100, figs. 6, 7).
  - a. Lateral chamber cavities low, but open—(see: Cole and Gravell, 1952, pl. 100, fig. 9).
    - 1′. Lateral chambers with thin floors and roofs in rude tiers—*P.* (*P.*) *palenquensis* (Vaughan) (see: Vaughan, 1929, pl. 7, fig. 2).
    - 2′. Lateral chambers with thick roofs and floors, overlapping—*P.* (*P.*) *advena* (Cushman) (see: Cole and Gravell, 1952, pl. 100, fig. 9).

b. Lateral chamber cavities slitlike—*P.* (*P.*) *perkinsi* (Vaughan) (see: Cole and Gravell, 1952, pl. 100, figs. 6-8).

B. Test normally umbonate with a distinct rim—**P.* (*P.*) *cedarkeysensis* Cole (see: Cole, 1944, pl. 26, figs. 1-3).

STRATIGRAPHIC RANGE

The largest number of species seemingly occur in sediments assigned at present to the middle Eocene where six apparently recognizable species are recorded. Two species occur in supposedly lower Eocene sediments, and two other species range from middle into the upper Eocene. Finally, the stratigraphic position of one species is in doubt. The following table lists these species in stratigraphic order:

LOWER EOCENE
P. (*P.*) *cedarkeysensis* Cole
zaragosensis (Vaughan)

MIDDLE EOCENE
P. (*P.*) *advena* (Cushman)
clarki (Cushman)
habanensis Cole and Bermudez
palenquensis (Vaughan)
penonensis Cole and Gravell
teres Cole and Gravell

MIDDLE TO UPPER EOCENE
P. (*P.*) *flintensis* (Cushman)
perkinsi (Vaughan)

UNCERTAIN POSITION (Caudri, 1944, p. 35)
P. (*P.*) *tobleri* Vaughan and Cole

The two species which have been recorded both from the middle and upper Eocene have the same stratigraphic range as do certain species of camerinids (Cole, 1958*b*, p. 264). Therefore, extreme caution must be used in dating sediments which contain these species.

* Originally, these specimens were identified as *P.* (*P.*) *zaragosensis* (Cole, 1942, p. 46). As only one vertical section of *P.* (*P.*) *zaragosensis* has been published, it is impossible to determine its variation. The internal features of the two species are similar, therefore, *P.* (*P.*) *cedarkeysensis* probably is a synonym of *P.* (*P.*) *zaragosensis*.

REVIEW OF SPECIES

Genus **Asterocyclina** Gümbel, 1870

Asterocyclina aster (Woodring) Pl. 53

1930. *Actinocyclina aster* Woodring, San Diego Soc. Nat. Hist., Trans., v. 6, No. 4, p. 152-155, pl. 14, figs. 3-6; pl. 16; pl. 17.
1938. *Aktinocyclina aster* Woodring, Berthiaume, Jour. Paleont., v. 12, No. 5, p. 496, 497, pl. 61, figs. 1-7.
1952. *Asterocyclina aster* (Woodring), Cole and Gravell, *idem*, v. 26, No. 5, p. 717, pl. 101, fig. 9.
1952. *Asterocyclina penonensis* Cole and Gravell, *idem*, p. 718, 719, pl. 96, fig. 1; pl. 98, figs. 1-8.
1958. *Asterocyclina penonensis* Cole and Gravell, Cole, Bull. Amer. Paleont., v. 38, No. 170, p. 202, pl. 22, fig. 7; pl. 25, fig. 20.

Discussion.—The vertical section (Pl. 53, fig. 3) of a topotype of *A. aster* should be compared with one of the illustrations given by Cole and Gravell (1952, pl. 98, fig. 3) of *A. penonensis.* There are no essential differences in internal structure.

Externally, the two species apparently are distinct. The type illustrations (Woodring, 1930, pl. 14, figs. 3, 5, 6) of *A. aster* show compressed, many rayed specimens with the rays extending from the periphery to a small central umbo, whereas *A. penonensis* is illustrated (Cole and Gravell, 1952, pl. 98, fig. 8) by inflated specimens with a few marginal rays. Although the illustrations of the external appearance of these specimens are typical, they do not show the entire range of variation.

Topotypes of *A. aster* used in this study are smaller than the specimens illustrated by Woodring. Although many of these are similar in external appearance to the illustrated specimens, there are several specimens which have nearly the same external appearance as do typical specimens of *A. penonensis.* Such specimens can not be distinguished from each other by external appearance.

The number, length of, and prominence of the rays represent an individual variation in a given species of larger Foraminifera. This same variation, found in species of *Asterocyclina*, has been demonstrated previously to occur in species of *Lepidocyclina* (Cole, 1958 *a*, p. 201).

The equatorial section reflects the external appearance inasmuch as the arrangement of the equatorial chambers is dependent on the number of rays. Therefore, individuals from the Cuban population show in equatorial section five to six rays, whereas those from the Californian population show five to thirteen rays with many individuals possessing eight rays. Such a difference between two localities is thought to be a racial variation rather than a specific distinction and to be ecologically rather than genetically controlled.

In the description of *A. aster* Woodring (1930, p. 155) noted the similarity between this species and *A. calita* (W. Berry) (1929, p. 143). *A. calita* is imperfectly described, therefore, it is impossible to relate it to *A. aster.* However, externally the two species seem to be the same. If the internal structure of *A. calita* is the same as that of *A. aster* the name *A. calita* will have priority.

Genus **Pseudophragmina** H. Douvillé, 1923

Subgenus **Proporocyclina** Vaughan and Cole, 1940

Pseudophragmina (Proporocyclina) clarki (Cushman) Pl. 52, figs. 3-11

1921. *Orthophragmina clarki* Cushman, U. S. Geol. Sur., Prof. Pap. 125, p. 41, 42, pl. 7, figs. 4, 5.
1922. *Orthophragmina peruviana* Cushman, in Bosworth, T. O., p. 138, 139, pl. 24, fig. 3.
1929. *Orthophragmina* (*Discocyclina*) *salensis* Berry, Jour. Washington Acad. Sci., v. 19, No. 7, p. 143, figs. 1, 2.
1932. *Discocyclina restinensis* Todd and Barker, Geol. Mag., v. 69, No. 822, p. 529-531, pl. 39, figs. 3, 4, 5, 7; text fig. 2.
1932. *Discocyclina peruviana* (Cushman), Todd and Barker, *idem*, p. 533-535, pl. 39, figs. 1, 2, 6, 8; text fig. 1.
1936. *Discocyclina clarki* (Cushman), Vaughan, Jour. Paleont., v. 10, No. 4, p. 255, 256, pl. 43, figs. 1, 2.
1938. *Discocyclina clarki* (Cushman), Berthiaume, *idem*, v. 12, No. 5, p. 496, pl. 61, fig. 12.
1945. *Pseudophragmina* (*Proporocyclina*) *peruviana* (Cushman), Vaughan, Geol. Soc. Amer., Mem. 9, p. 95, 96, pl. 39, figs. 1-4.

Discussion.—The equatorial section of P. (P.) *clarki* (Cushman) (Pl. 52, fig. 11), P. (P.) *peruviana* (Cushman) (Pl. 52, fig. 10; Vaughan, 1945, pl. 39, figs. 3, 4), P. (P.) *habanensis* Cole and Bermudez (1947, pl. 19, fig. 8) and P. (P.) *tobleri* Vaughan and Cole (1941, pl. 22, figs. 3, 4) are nearly identical. Although Vaughan (1945, p. 88) placed P. (P.) *tobleri* in the "group of *Pseudophragmina* (*Proporocyclina*) *flintensis*," he separated it from the other species which he included in this group by the characteristic "Peripheral equatorial chambers not elongate radially."

The embryonic chambers of P. (P.) *clarki* and the three other species similar to it are consistently larger than those in P. (P.) *flintensis.* The equatorial chambers are less elongate radially, the radial chamber walls are less complete and more irregular than those of P. (P.) *flintensis* (compare fig. 10, Pl. 52 with fig. 1, Pl. 50). Thus, in equatorial section it is possible to separate these four species from P. (P.) *flintensis.*

If the illustration of P. (P.) *peruviana* given by Vaughan (1945, pl.

39, fig. 2) is compared with the figure 5, Plate 52 the similarity between a typical specimen from Peru, and one from California, identified as *P.* (*P.*) *clarki*, will be apparent.

The two vertical sections (Pl. 52, figs. 6, 8) of specimens from near Punta Arenas, Peru, were made from specimens identified by the late T. W. Vaughan. These specimens are thicker through the center and have a slightly larger umbonal area than does the specimen from El Alto, Peru, illustrated by Vaughan (1945, pl. 39, fig. 2). The specimen from El Alto is similar to specimens named *Discocyclina restinensis* by Todd and Barker (1932, p. 529). Vaughan (1945, p. 95) correctly placed *P.* (*P.*) *restinensis* in the synonymy of *P.* (*P.*) *peruviana.*

As *P.* (*P.*) *peruviana* has the same characteristics as does *P.* (*P.*) *clarki* these species are combined. As *P.* (*P.*) *habanensis* and *P.* (*P.*) *tobleri* (see Key to Type II species) apparently can be separated from each other and from *P.* (*P.*) *clarki*, they are retained as valid species.

Pseudophragmina (Proporocyclina) flintensis (Cushman)
Pl. 50; Pl. 51; Pl. 52, figs. 1, 2

1917. *Orthophragmina flintensis* Cushman, U. S. Geol. Sur., Prof. Pap. 108-G, p. 115, 116, pl. 40, figs. 1, 2.
1919. *Orthophragmina antillea* Cushman (part), Carnegie Inst. Washington, Publ. 291, p. 55, 56, pl. 2, figs. 2 (center), 3 (lower left).
1921. *Orthophragmina flintensis* Cushman, Cushman, U. S. Geol. Sur., Prof. Pap. 125, p. 44, pl. 9, figs. 3-6.
1926. *Discocyclina mirandana* Hodson, Bull. Amer. Paleont., v. 12, No. 47, p. 8, pl. 1, figs. 3, 10, 13.
1927. *Discocyclina clarki* Cole (not Cushman), *idem*, v. 14, No. 51, p. 36, pl. 2, fig. 31.
1928. *Discocyclina* (*Discocyclina*) *citrensis* Vaughan, Florida Geol. Sur., 19th Ann. Rept., p. 159, 160, pl. 2, figs. 1-5.
1929. *Discocyclina cushmani* Vaughan, U. S. Nat. Mus., Proc., v. 76, Art. 3, p. 11-13, pl. 3, figs. 1-4.
1929. *Discocyclina perpusilla* Vaughan, *idem*, p. 9-11, pl. 2, figs. 3, 4, 5, 5 *a*.
1930. *Discocyclina psila* Woodring, San Diego Soc. Nat. Hist., Trans., v. 6, No. 4, p. 148-151, pl. 14, figs. 2, 4-6; pl. 15; pl. 17.
1932. *Discocyclina* (*Discocyclina*) *blumenthali* Gorter and van der Vlerk, Leidsche Geol. Meded., v. 4, p. 111, pl. 16, figs. 2-4.
1932. *Discocyclina* (*Discocyclina*) *flintensis* (Cushman), Gorter and van der Vlerk, *idem*, p. 111, 112, pl. 16, figs. 5, 6.
1936. *Discocyclina psila* Woodring, Vaughan, Jour. Paleont., v. 10, No. 4, p. 256, pl. 42, fig. 7, 8.
1938. *Discocyclina perpusilla psila* Woodring, Berthiaume, *idem*, v. 12, No. 5, p. 496, pl. 61, figs. 8-11.
1941. *Pseudophragmina* (*Proporocyclina*) *citrensis* (Vaughan), Cole, Florida Geol. Sur., Bull. 19, p. 47, pl. 17, figs. 6, 7.
1941. *Pseudophragmina* (*Proporocyclina*) *flintensis* (Cushman), Vaughan and Cole, Geol. Soc. Amer., Sp. Pap. 30, p. 61, 62, pl. 20, figs. 8, 9.
1942. *Pseudophragmina* (*Proporocyclina*) *pertenuis* Bronnimann, Schweiz. Paläont. Abh., v. 63, p. 1-13, pls.

1944. *Pseudophragmina* (*Proporocyclina*) *citrensis* (Vaughan) Cole, Florida Geol. Sur., Bull. 26, p. 83, 84, pl. 1, fig. 9; pl. 18, fig. 10; pl. 25, figs. 1-6; pl. 28, fig. 6.

1944. *Pseudophragmina* (*Proporocyclina*) *flintensis* (Cushman), Cole, *idem*, p. 84, pl. 25, figs. 7-9.

1945. *Pseudophragmina* (*Proporocyclina*) *blumenthali* (Gorter and van der Vlerk), Vaughan, Geol. Soc. Amer., Mem. 9, p. 94.

1945. *Pseudophragmina* (*Proporocyclina*) *citrensis* (Vaughan), Vaughan, *idem*, p. 89.

1945. *Pseudophragmina* (*Proporocyclina*) *cushmani* (Vaughan), Vaughan, *idem*, p. 94, 95, pl. 38, figs. 1-3 *a*.

1945. *Pseudophragmina* (*Proporocyclina*) *flintensis* (Cushman), Vaughan, *idem*, p. 89-92, pl. 36; pl. 37, fig. 1.

1945. *Pseudophragmina* (*Proporocyclina*) *mirandana* (Hodson), Vaughan, *idem*, p. 92-94, pl. 37, figs. 2, 2 *a*, 3.

1945. *Pseudophragmina* (*Proporocyclina*) *palmerae* Vaughan, *idem*, p. 97, pl. 41.

1947. *Pseudophragmina* (*Proporocyclina*) *cushmani* (Vaughan), Cole and Bermudez, Bull. Amer. Paleont., v. 31, No. 125, p. 206, 207, pl. 6, figs. 1-4; pl. 7, fig. 9.

1949. *Pseudophragmina* (*Proporocyclina*) *flintensis* (Cushman), Cole, Jour. Paleont., v. 23, p. 274, pl. 54, figs. 1-4.

1952. *Pseudophragmina* (*Proporocyclina*) *convexicamerata* Cole and Gravell, *idem*, v. 26, No. 5, p. 721, 722, pl. 101, figs. 1-3; pl. 102, figs. 12-19.

1952. *Pseudophragmina* (*Proporocyclina*) *cushmani* (Vaughan), Cole and Gravell, *idem*, p. 722, 723, pl. 99, figs. 1-5.

1952. *Pseudophragmina* (*Proporocyclina*) *psila* (Woodring), Cole and Gravell, *idem*, p. 725, pl. 101, figs. 4, 5; pl. 102, figs. 1-10.

1952. *Pseudophragmina* (*Proporocyclina*) *perpusilla* (Vaughan), Cole and Gravell, *idem*, p. 722, pl. 102, fig. 11.

1957. *Pseudophragmina* (*Proporocyclina*) *flintensis* (Cushman), Cole, U. S. Geol. Sur., Prof. Pap. 244, p. 35, pl. 28, figs. 7-16.

Discussion.—The following middle and upper Eocene species of *Pseudophragmina* (*Proporocyclina*) have identical equatorial sections. In each case a reference is given to a typical illustration.

MIDDLE EOCENE

P. (*P.*) *convexicamerata* Cole and Gravell (1952, pl. 101, figs. 1-3), Cuba.
cushmani (Vaughan) Cole and Bermudez, 1947, pl. 6, fig. 1), Cuba.
perpusilla (Vaughan) (Pl. 50, fig. 7), Mexico.
psila (Woodring) (Pl. 50, figs. 2, 4), California.

UPPER EOCENE

P. (*P.*) *blumenthali* (Gorter and van der Vlerk) (1932, pl. 16, fig. 4), Venezuela.
citrensis (Vaughan) (Pl. 50, fig. 5), Florida.
flintensis (Cushman) (Pl. 50, figs. 1, 3), Florida and Texas.
mirandana (Hodson) (Bronnimann, 1942, pl. 2, figs. 11-14), Venezuela.

The recognition of these species has been based mainly on the external form and the internal structures shown in vertical section inasmuch as they have similar equatorial sections. If these are distinct species, readily recognizable, it should be possible to prepare a key based on external appearance and the characteristics of the vertical section. Such a key was prepared and is given to demonstrate that several of the so-called species have the same features:

A. Test normally compressed, nonumbonate
   1. Lateral chamber cavities open—*P.* (*P.*) *blumenthali, P.* (*P.*) *mirandana, P.* (*P.*) *perpusilla*
   2. Lateral chamber cavities slitlike—*P.* (*P.*) *psila*

B. Test with a flat rim and sharply demarcated large umbo—*P.* (*P.*) *cushmani*

C. Test with a small, not sharply demarcated umbo—*P.* (*P.*) *flintensis*

D. Test evenly lenticular—*P.* (*P.*) *citrensis, P.* (*P.*) *convexicamerata*

As the species are studied in more detail the confusion becomes compounded. If the illustrations (Cole and Gravell, 1952, pl. 102, figs. 15, 16) of *P.* (*P.*) *convexicamerata* from the middle Eocene of Cuba are compared with the illustration (Pl. 51, fig. 15) of a specimen of *P.* (*P.*) *citrensis* from the upper Eocene of Florida, it will be observed that they are practically identical.

Moreover, if the shape of the floors and roofs and the cavities of the lateral chambers only are compared, it will be observed that they are the same in *P.* (*P.*) *citrensis* (Pl. 51, fig. 15), *P.* (*P.*) *convexicamerata* (Cole and Gravell, 1952, pl. 102, figs. 15, 16) and *P.* (*P.*) *perpusilla* (Pl. 51, figs. 9, 10). Therefore, the only difference between *P.* (*P.*) *perpusilla* and the other two species is in the number of lateral chambers developed on each side of the equatorial layer. A difference of this kind is more readily explained as an environmentally or individually controlled one than a genetically produced one.

In the camerinids it was postulated that the thin fragile *Operculinoides* of the kind previously called *O. cushmani* were the same as the robust kind called *O. antillea* (Cole, 1958 *a*, p. 191), but under different environmental conditions the development of the test varied. This same explanation appears to account for the development of more numerous lateral chambers in *P.* (*P.*) *convexicamerata* and *P.* (*P.*) *citrensis.*

If the illustration of a part of a vertical section (Vaughan, 1929, pl. 3, fig. 3) through the umbonal area of *P.* (*P.*) *cushmani* is compared with a similar section (Cole and Gravell, 1952, pl. 102, fig. 14) of *P.* (*P.*) *convexicamerata*, the similarity of internal structure will be observed. Thus, there is a series of specimens to which different specific names have been given although these specimens have the same internal structure.

If the specimens were compressed, they have been called *P.* (*P.*) *perpusilla*, whereas lenticular specimens have been named *P.* (*P.*) *convexicamerata* if they occurred in the middle Eocene or *P.* (*P.*) *citrensis* if they occurred in the upper Eocene. If the specimens had a strong umbo, they have been referred to *P.* (*P.*) *cushmani.*

Although specimens of *P.* (*P.*) *perpusilla* from the Guayabal formation normally have open lateral chamber cavities (figs. 9, 10, Pl. 51), other specimens have slitlike lateral chamber cavities (fig. 6, Pl. 51). Other specimens (fig. 3, Pl. 51) are intermediate. This same development occurred in the specimens from the Orocopia Mountains (compare fig. 1 with fig. 7, Pl. 51) which were identified as *P.* (*P.*) *psila.*

P. (*P.*) *mirandana* from Venezuela (Vaughan, 1945, pl. 37, fig. 3) is identical with specimens of *P.* (*P.*) *perpusilla* (Pl. 51, fig. 9). Cole (1957, p. 35) has suggested that *P.* (*P.*) *citrensis* and *P.* (*P.*) *mirandana* are synonyms of *P.* (*P.*) *flintensis.*

This suggestion is strengthened if the shape and the arrangement of the lateral chambers are compared between specimens illustrated in this article as follows: *P.* (*P.*) *perpusilla* (fig. 10, Pl. 51) to *P.* (*P.*) *citrensis* (fig. 15, Pl. 51) to *P.* (*P.*) *flintensis* (fig. 13, Pl. 51) to *P.* (*P.*) *flintensis* (fig. 14, Pl. 51).

Thus, it would appear that *P.* (*P.*) *citrensis, P.* (*P.*) *convexicamerata, P.* (*P.*) *cushmani, P.* (*P.*) *mirandana, P.* (*P.*) *perpusilla* and *P.* (*P.*) *psila* are synonyms of *P.* (*P.*) *flintensis* and that this species ranges from middle to upper Eocene. *P.* (*P.*) *blumenthali* is inadequately illustrated, but it apparently is another synonym of *P.* (*P.*) *flintensis.*

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Note: see Vaughan, 1945, for additional references.

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PLATES

EXPLANATION OF PLATE 50

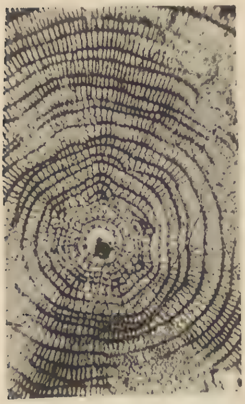
Figure Page

1-7. **Pseudophragmina (Proporocyclina) flintensis** (Cushman) 420

1-7. Equatorial sections, x 40.

- 1, 3. Originally identified as this species.
- 2, 4. Topotypes of *P.* (*P.*) *psila* (Woodring).
- 5. Originally identified as *P.* (*P.*) *citrensis* (Vaughan).
- 6. Originally identified as *P.* (*P.*) *psila* (Woodring).
- 7. Topotype of *P.* (*P.*) *perpusilla* (Vaughan).

1, 5. Loc. 7 (Fla.)—see text for locality descriptions.
2, 4. Loc. 5 (Cal.)
3. Loc. 8 (Texas)
6. Loc. 1 (Cal.)
7. Loc. 6 (Mexico)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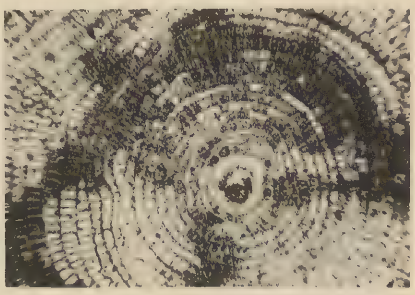
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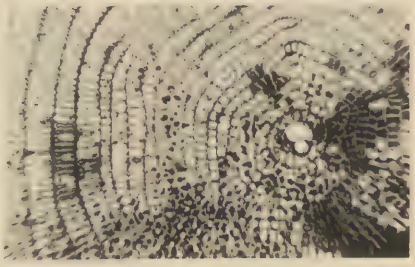
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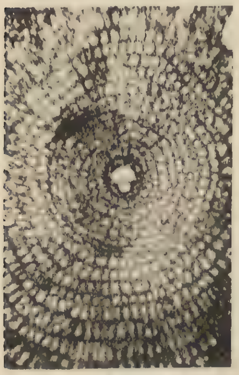
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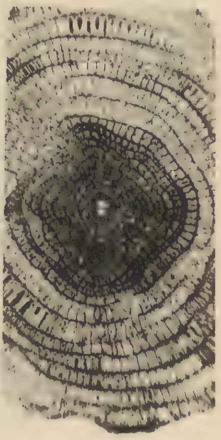
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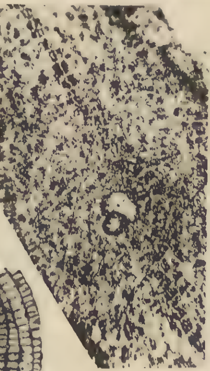
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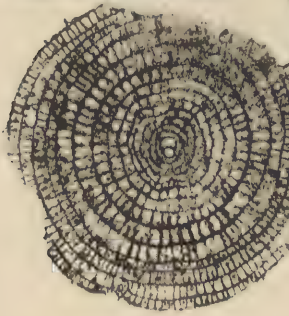
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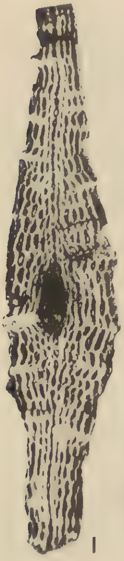
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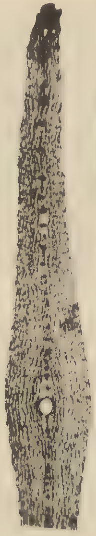
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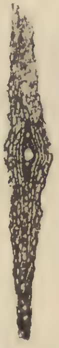
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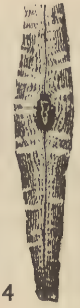
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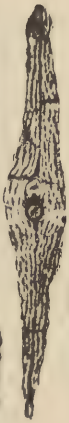
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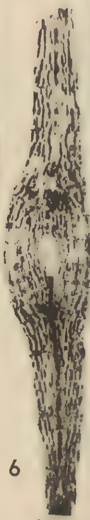
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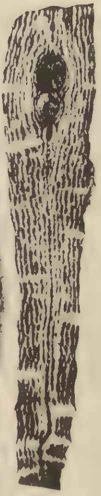
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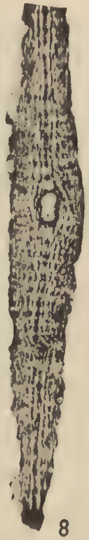
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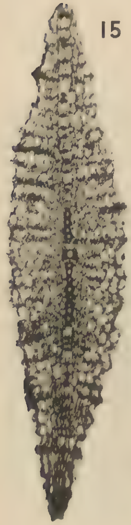
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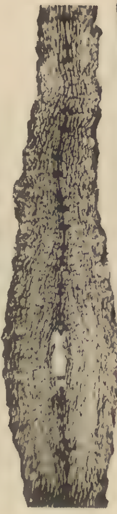
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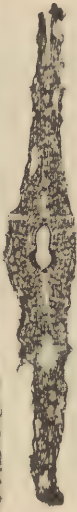
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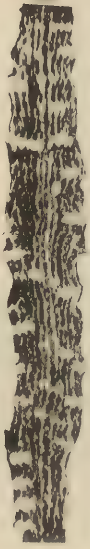
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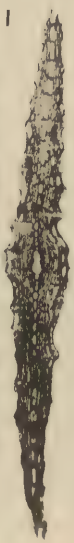
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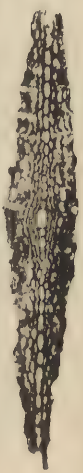
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EXPLANATION OF PLATE 51

Figure Page

1-15. **Pseudophragmina (Proporocyclina) flintensis** (Cushman).......... 420

1-15. Vertical sections, x 40, except 4, x 20.

1, 4, 5, 7, 11. Originally identified as *P.* (*P.*) *psila* (Woodring).

2, 12-14. Originally identified as this species.

3, 6, 9, 10. Topotypes of *P.* (*P.*) *perpusilla* (Vaughan).

8. Topotype of *P.* (*P.*) *psila* (Woodring).

15. Originally identified as *P.* (*P.*) *citrensis* (Vaughan).

1, 4, 5, 7, 11. Loc. 1. (Cal.)—see text for locality descriptions.

2, 14, 15. Loc. 7 (Fla.)

3, 6, 9, 10. Loc. 6 (Mexico)

8. Loc. 5 (Cal.)

12, 13. Loc. 8 (Texas)

Explanation of Plate 52

Figure Page

1, 2. **Pseudophragmina (Proporocyclina) flintensis** (Cushman) 420

- 1. Vertical section, x 40.
- 2. Vertical section, x 20, in matrix.

3-11. **Pseudophragmina (Proporocyclina) clarki** (Cushman) 419

- 3-9. Vertical sections, 3-6, x 40; 7-9, x 20.
    - 3, 7. Originally identified as this species.
    - 4, 5, 9. Specimens identified by Vaughan as this species.
    - 6, 8. Specimens identified by Vaughan as *P.* (*P.*) *peruviana* (Cushman).
- 10, 11. Equatorial sections, x 40.
    - 10. Specimen identified by Vaughan as *P.* (*P.*) *peruviana* (Cushman).
    - 11. Specimen identified by Vaughan as this species.

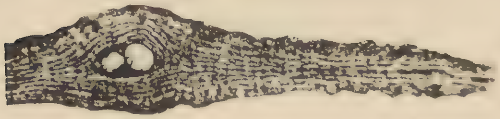
(Note: Fig. 3 is the same specimen as the top one of fig. 7 and fig. 4 is the same specimen as fig. 9).

1, 2. Loc. 1 (Cal.)—see text for locality descriptions.

3, 7. Loc. 3 (Cal.)

4, 5, 9, 11. Loc. 4 (Cal.)

6, 8, 10. Loc. 9 (Peru)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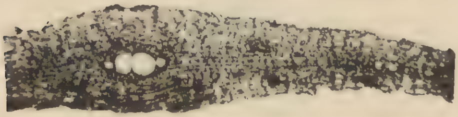
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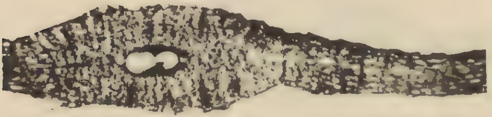
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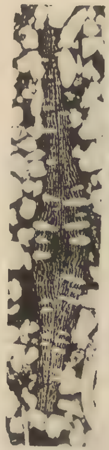
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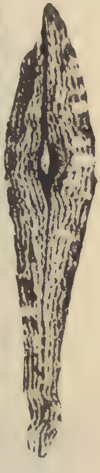
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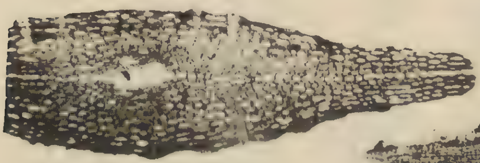
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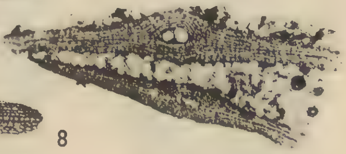

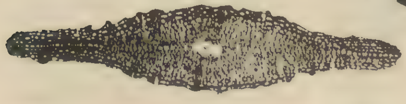
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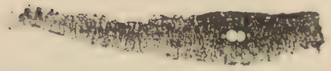
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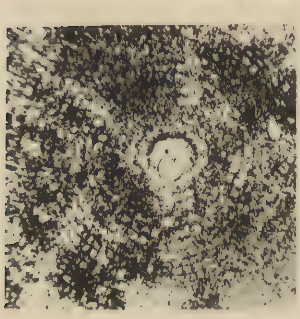

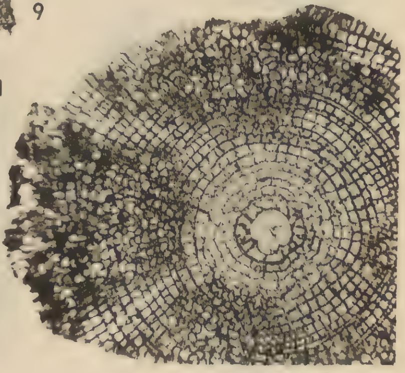

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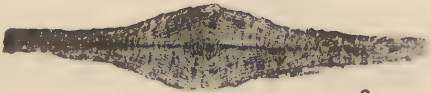
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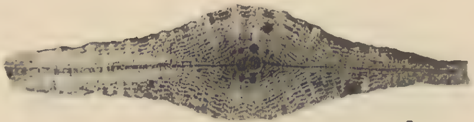
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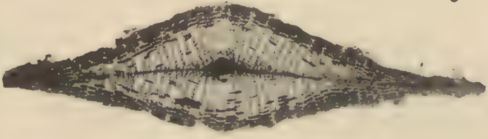
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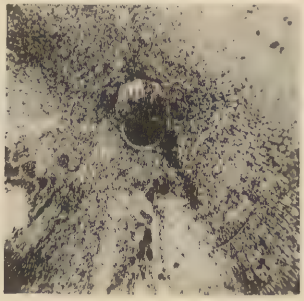
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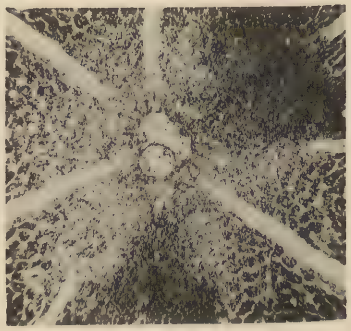

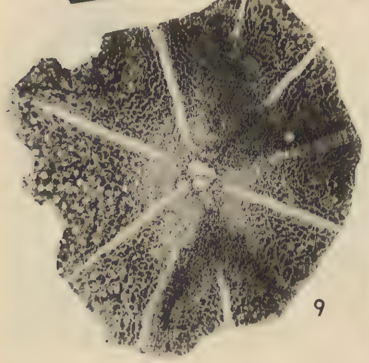
9

EXPLANATION OF PLATE 53

Figure		Page
1-9.	**Asterocyclina aster** (Woodring)	418

1-6. Vertical sections; 1, 5, x 40; 2-4, 6, x 20.

1. Small specimen, not centered, to illustrate the lateral chambers, pillars and equatorial layer.

2-4, 6. Topotypes.

5. Part of the specimen, fig. 4, enlarged, to show details.

7-9. Equatorial sections; 7, 8, x 40; 9, x 20.

7, 8. Parts of equatorial sections of topotypes to illustrate embryonic chambers; 8, part of fig. 9, enlarged.

9. Topotype to illustrate embryonic and equatorial chambers and the pattern of the rays.

1. Loc. 1 (Cal.)—see text for locality descriptions.

2-9. Loc. 5 (Cal.)

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